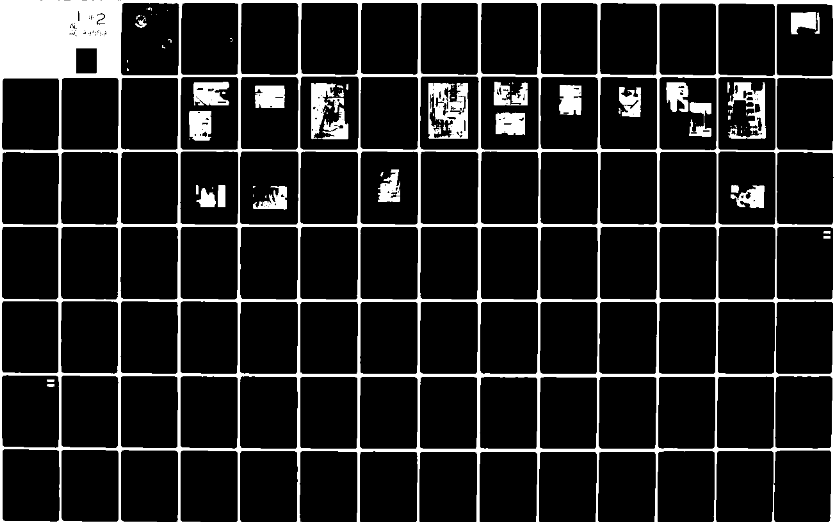
AD-A099 559 SYSTECH CORP XENIA OH F/G 13/2

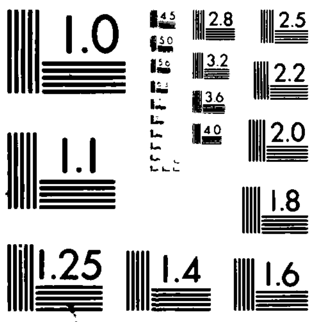
TEST AND EVALUATION OF THE HEAT RECOVERY INCINERATOR SYSTEM AT --ETC(U)

MAY 81 N68305-80-C-0006

UNCLASSIFIED CEL-CR-81.012 NL

1 of 2





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD A099559

LEVEL

CR 81.012

CIVIL ENGINEERING LABORATORY
Naval Construction Battalion Center
Port Hueneme, CA 93043

Sponsored by
NAVAL FACILITIES ENGINEERING COMMAND

TEST AND EVALUATION OF THE HEAT RECOVERY INCINERATOR SYSTEM AT NAVAL STATION, MAYPORT, FLORIDA

May 1981

An Investigation Conducted by
SYSTECH CORPORATION
245 North Valley Road
Xenia, OH 45385

N68305-80-C-0006

Approved for public release; distribution unlimited.

FILE COPY

81 6 01 065

1MCL11

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE — READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 11 CR-81.012
2. GOVT ACCESSION NO.: AD-A099599
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): 6 Test and Evaluation of the Heat Recovery Incinerator System at Naval Station, Mayport, Florida.
5. TYPE OF REPORT & PERIOD COVERED: Final rept. June 1980-April 1981,
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s):
8. CONTRACT OR GRANT NUMBER(s): 15 N68305-80-C-0006 new 12 1..1
9. PERFORMING ORGANIZATION NAME AND ADDRESS: SYSTECH CORPORATION, 245 North Valley Road, Xenia, Ohio 45385
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 16 Z0350-01-421B
11. CONTROLLING OFFICE NAME AND ADDRESS: Civil Engineering Laboratory, Naval Construction Battalion Center, Port Hueneme, CA 93043
12. REPORT DATE: 11 May 1981 17 Z03500141
13. NUMBER OF PAGES:
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS (of this report): Unclassified
15a. DECLASSIFICATION DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited.
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):
18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number): Solid waste incineration; resource recovery; energy conversion; stack emissions; heat recovery incinerators
20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

This report describes test and evaluation of the two-ton/hr heat recovery incinerator (HRI) facility located at Mayport Naval Station, FL, carried out during November and December 1980. The tests included: (1) Solid Waste: characterization, heating value, and ultimate analysis, (2) Ash: moisture, combustibles, and heating values of both bottom and cyclone ashes; EP toxicity

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

NW 412363

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. (continued)

tests on leachates from both bottom and cyclone ashes; trace metals in cyclone particulates, (3) Stack Emissions: particulates (quantity and size distribution), chlorides, oxygen, carbon dioxide, carbon monoxide, and trace elements, and (4) Heat and Mass Balance: all measurements required to carry out complete heat and mass balance calculations over the test period.

The overall thermal efficiency of the HRI facility while operating at approximately 1.0 ton/hr was found to be 49% when the primary Btu equivalent of the electrical energy consumed during the test program was included. For additional details, contact Dr. S. C. Garg, (805) 982-4675.

Accession For	
NTIS GRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A	

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

CONTENTS

CONTENTS (continued)

FIGURES

FIGURES (continued)

TABLES

TABLES (continued)

ACKNOWLEDGMENT

This evaluation was performed under Department of Defense (DOD) Contract No. N68305-80-C-0006. The project was supported in part by the Environmental Protection Agency (EPA) Contract No. 68-01-6071, Assignment No. 6.

The authors wish to gratefully acknowledge the support and cooperation of Dr. Suresh C. Garg of the Navy Civil Engineering Laboratory and Messrs. David Sussman and Randolph Chrismon of the EPA, Office of Solid Waste.

We also wish to express our gratitude to Dr. Suresh C. Garg and Mr. Philip Stone for personally helping perform the test at Mayport, Florida.

The cooperation of Chief Paul Kendricks of Naval Station Mayport and Mr. David Pitts and his crew from Southern Technology was also appreciated.

We are also thankful to the 13 engineers, scientists, and technicians of SYSTECH Corporation who traveled to Mayport, Florida, and monitored the operation of the system around the clock.

SECTION 1

INTRODUCTION

There is little data available on small scale solid waste processing and heat recovery installations to permit determination of optimum cost effective design in the 20 to 60 tons per day (TPD) range.

The Navy has recently installed two 2 tons per hour (TPH) nominal capacity heat recovery incinerators (HRI), one at Naval Station (NS), Mayport, and the other at Naval Air Station (NAS), Jacksonville, both in Florida. The Mayport HRI is a field-erected, refractory-lined incinerator of a simple design which permits incineration of unprocessed Navy base waste. The Jacksonville NAS HRI, however, is a packaged incinerator with a front-end processing line to remove glass and metals and to reduce the waste size. The Civil Engineering Laboratory (CEL) is now evaluating the two concepts in an effort to develop guidelines for future Navy procurement of HRIs. The Civil Engineering Laboratory contracted SYSTECH Corporation to evaluate the technical and environmental performance of the Naval Station, Mayport heat recovery incinerator. The Environmental Protection Agency, Office of Solid Waste (EPA/OSW) also provided funding so that SYSTECH could perform an expanded environmental evaluation of the heat recovery incinerator.

A detailed test protocol was assembled for a continuous 120-hr test of the facility. On November 17, 1980, the test commenced according to this plan. During the twelfth hour of the test, the hydraulically operated ram feeder of the incinerator failed (see Figure 1-1) making it impossible to feed refuse into the incinerator. The test continued for another 48 hours while burning only waste oil to generate steam. Daily characterization of the refuse received was continued by SYSTECH during this period. At the end of this period it was concluded that the ram feeder could not be fixed without extensive repairs and, therefore, the test was aborted.

With the funds remaining, an abbreviated test of 78 hours was carried out after the ram feeder was repaired. This test successfully occurred on December 8, 9, and 10, 1980. During this 78-hr test, the refuse composition was determined by Sanders and Thomas Inc. The moisture content and chemical properties of the refuse determined by SYSTECH in November were applied to the December composition because these analyses were not repeated in December.

All data collected during the 78-hr December 1980 test were analyzed by SYSTECH. The results form the basis of this report. The boiler performance experienced during the burning of waste oil in November is also reported herein.

Figure 1-1. Hydraulically operated ram feeder.

SECTION 2

PLANT DESCRIPTION

The Naval Station, Mayport, Florida, heat recovery incinerator system is located next to the station's fossil fuel power plant. The 40- to 50-TPD incinerator system is housed in a 140-ft × 180-ft building on a 240-ft × 300-ft site.

The facility consists of a tipping floor, an open storage pit, an overhead clamshell crane, an incinerator-boiler unit, and a flue gas handling system (including a cyclone dust collector). The facility layout is shown in Figure 2-1. A cross section of the equipment is shown in Figure 2-2.

RECEIVING AND STORAGE

The receiving and storage area shown in Figure 2-3 consists of a tipping floor and a reinforced concrete storage pit. Storage for 24 hours of operation is provided in the storage pit. A large, open-top container is provided to dispose of large metallic waste items.

CRANE SYSTEM

The crane system consists of a Cleveland Tram clamshell. It operates by radio control and transfers refuse from the storage pit as shown in Figure 2-4 to the incinerator feeder as shown in Figure 2-5. Load cells built into the tram rail provide a weight measurement of the refuse to be dropped into the incinerator. Measurement is taken when the crane is directly over the loading hopper.

INCINERATOR FEED SYSTEM

The incinerator feed system consists of a ram feeder-hopper assembly (see Figures 2-5 and 2-6) which includes a feed chute with hydraulically operated hinged cover doors and a structurally reinforced ram powered by two hydraulic cylinders. The feeder hopper has a holding capacity of 20 yd^3 with the cover doors closed. The feeder ram automatically pushes the refuse from the hopper into the furnace at a rate that is compatible with the furnace capacity.

PRIMARY COMBUSTION AND BURNER SYSTEM

Refuse, compacted by the ram feeder, enters the primary furnace chamber (see Figure 2-6) through the charging opening. The neck of the charging opening is water cooled to protect it from the furnace heat. Combustion of

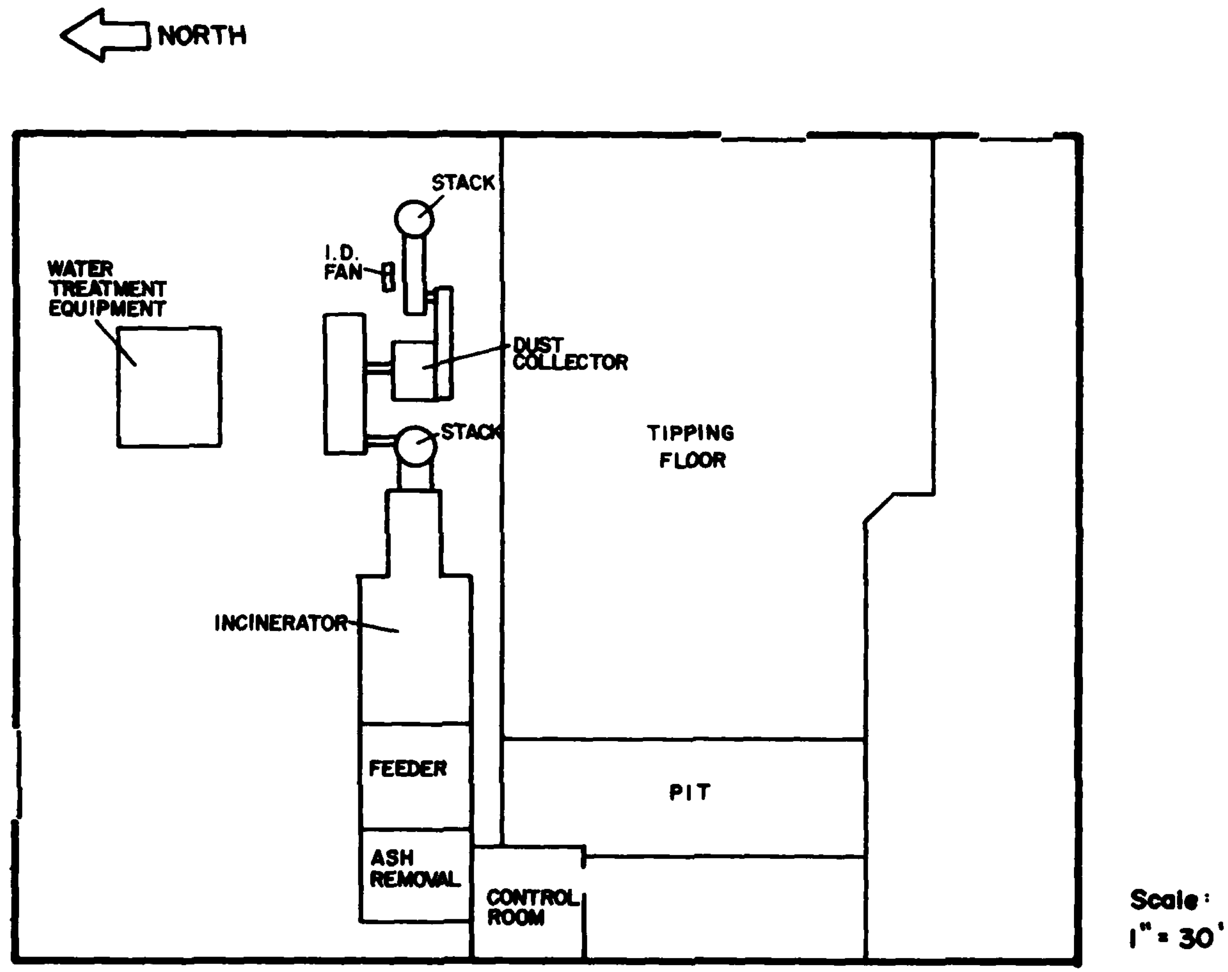


Figure 2-1. Layout of Mayport Naval Station heat recovery incineration facility.

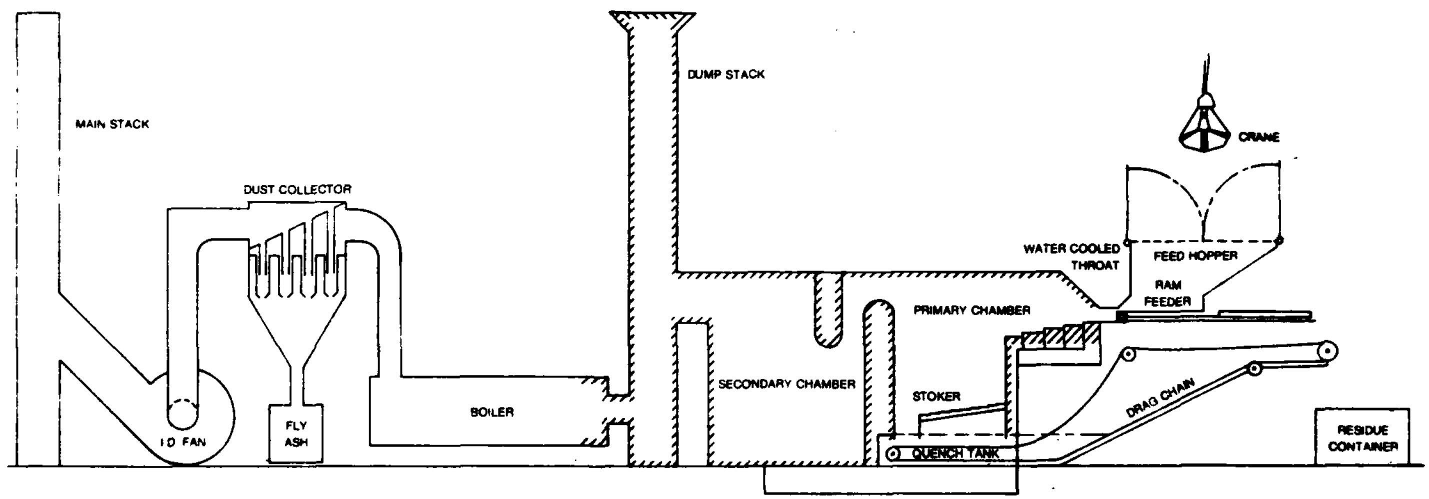


Figure 2-2. Cross section of incineration heat recovery system.

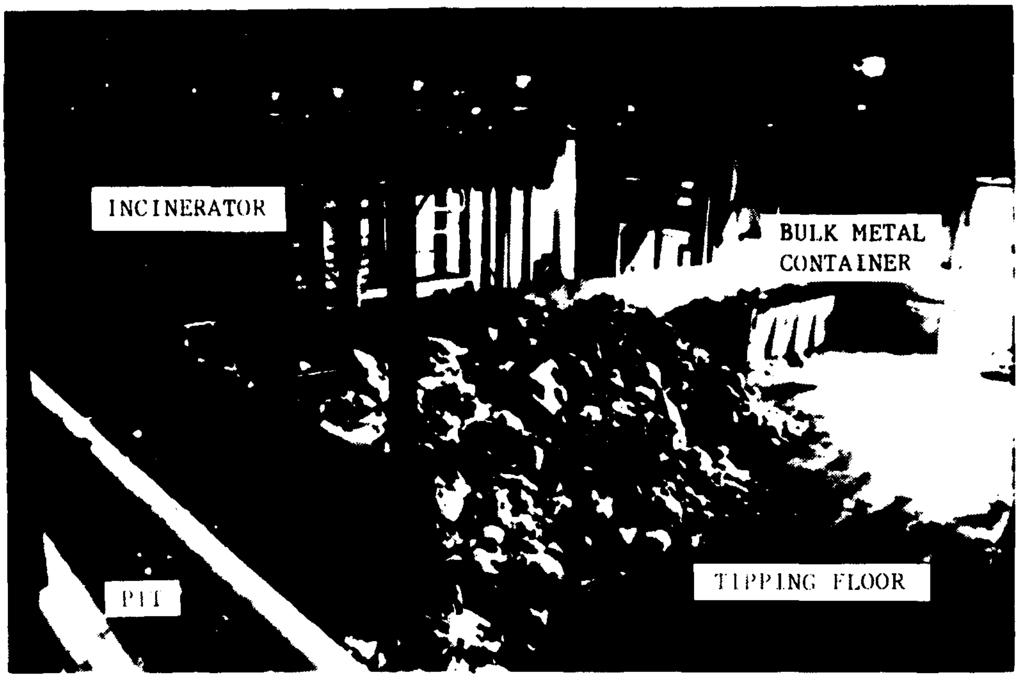


Figure 2-3. View of tipping floor storage pit and reject metals container.

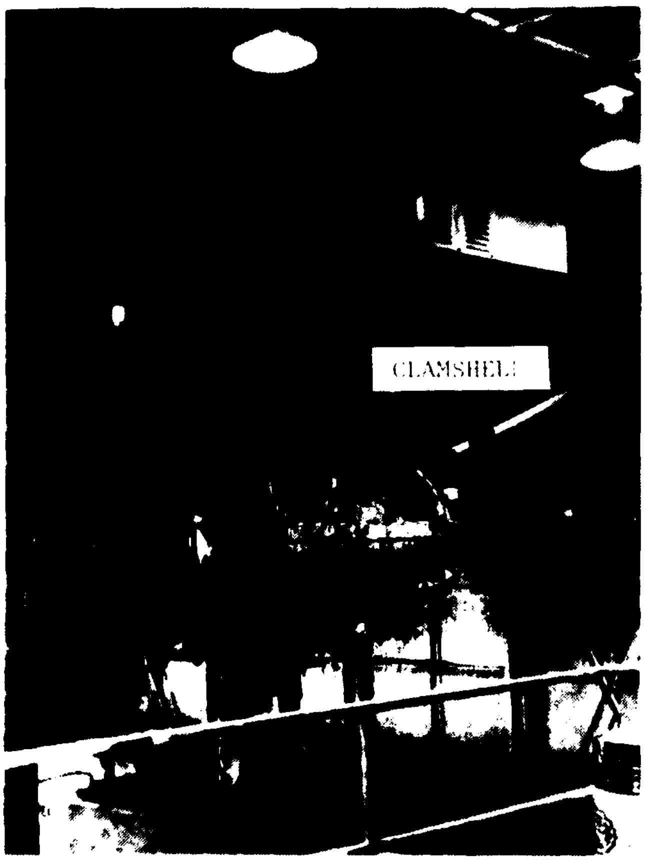


Figure 2-4. Overhead clamshell crane lifting solid waste out of pit.

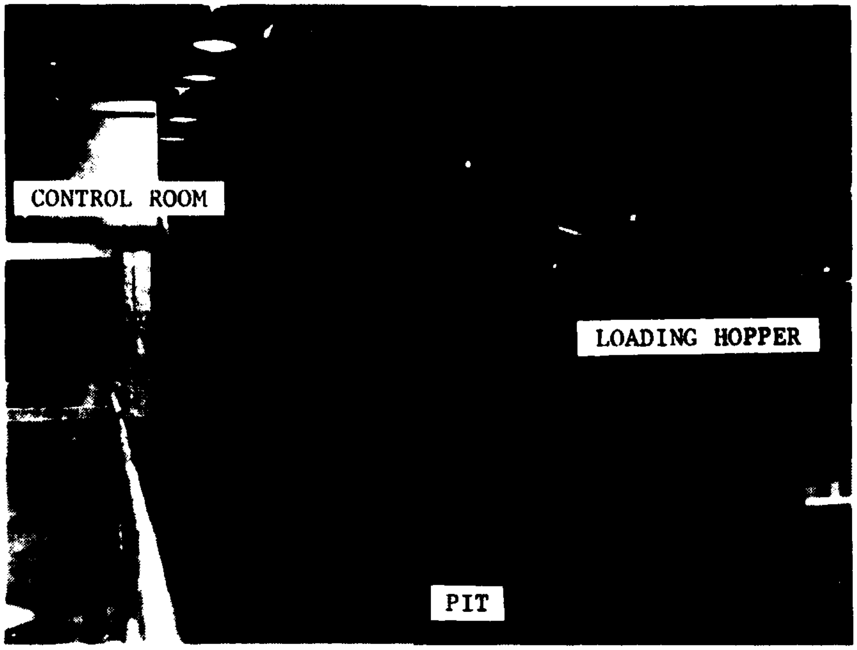


Figure 2-5. Clamshell crane in position over incinerator hopper.

refuse as it passes through the charging opening is inhibited by the compacting action of the ram. This same compacting action also helps avoid overheating of the charging opening. The refuse is dried and ignited on an inclined refractory hearth located just inside the water-cooled throat. The dried refuse is forced off this hearth by the successive loading action of the feed ram. This refractory hearth section was designed with underfire air jets that are no longer in service. Use of the jets was found to cause extensive slagging in this portion of the hearth.

A Hauck oil-fired burner, Model No. PRW 112.45, Spec. T5982, is provided in one of the primary furnace sidewalls about 3 feet from the charging opening as shown in Figure 2-6. The function of this burner is to ignite the refuse as it enters the furnace and to aid in drying wet refuse (if required). The burner is equipped with a continuous gas pilot so that waste oil may be burned.

The primary combustion chamber is designed to liberate 20 $\times$ 10^6 Btu/hr. This liberation is equivalent to 2 TPH of the anticipated mixture of Type 1 and Type 2 wastes having a combined heat content of 5000 Btu/lb.

STOKER SYSTEM

By the time the refuse has advanced the length of the hearth, it is dried, ignited, and partially burned. It is then pushed off the hearth,

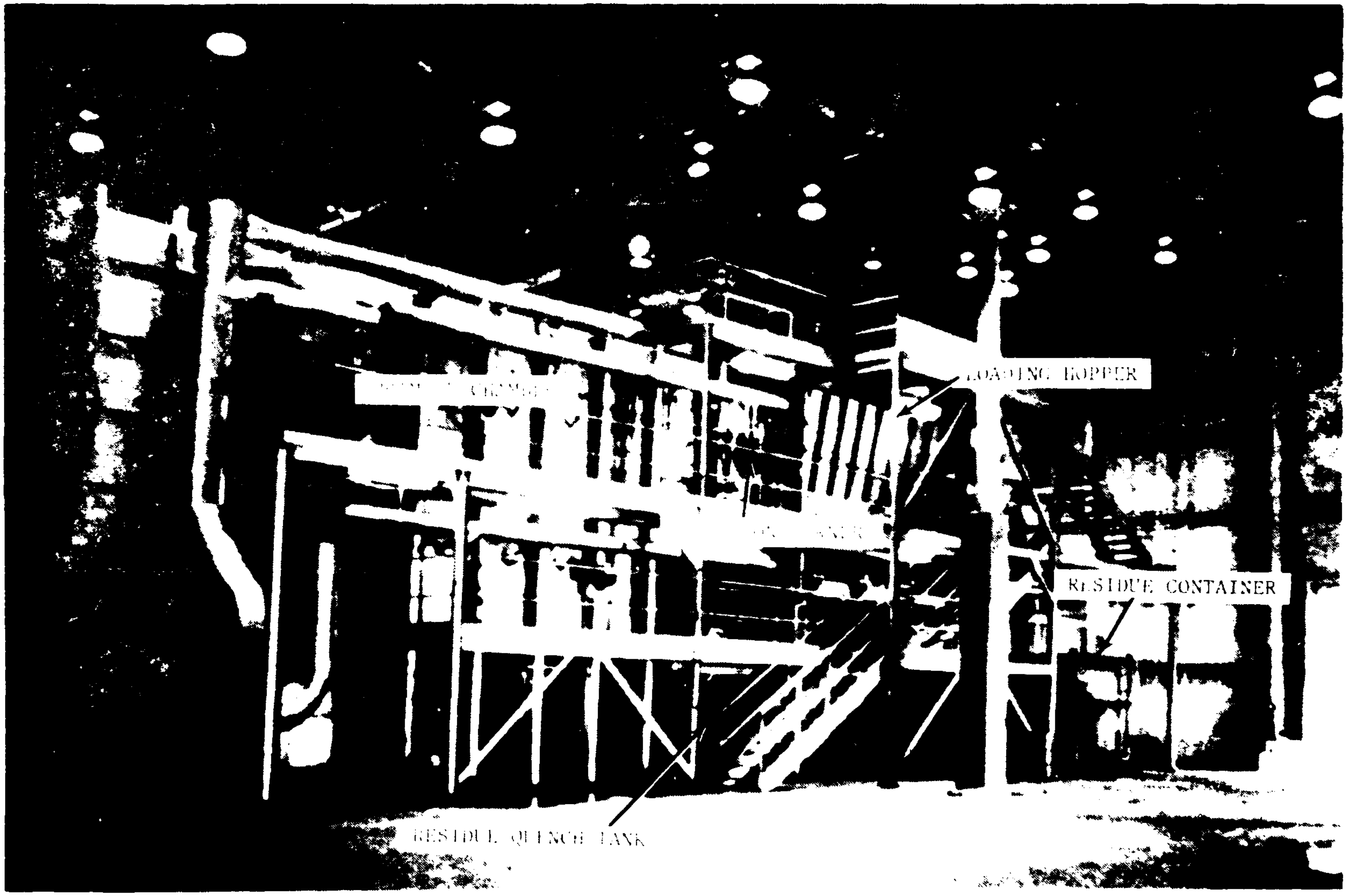


Figure 2-6. View of incinerator showing primary chamber loading hopper, ignition burner, ash quench tank, and drag chain conveyor.

and it tumbles several feet down to the stoker grate. The stoker, manufactured by the Detroit Stoker Company, consists of alternate rows of fixed and reciprocating cast iron plates in a series of shallow steps arranged to provide an overall downward slope of approximately 6°.

ASH REMOVAL SYSTEM

The burned-out ash and noncombustible materials drop off the end of the grate into a large tank of water (see Figure 2-6) which serves to quench and cool the ash residue. A continuous drag flight conveyor powered by a 7.5-hp motor runs below the water level of the quench tank, collecting the ash residue at the bottom of the tank and moving it up an elevating incline to the unloading point. The ash then drops into an open-top container as shown in Figure 2-6.

SECONDARY COMBUSTION CHAMBER AND BURNER SYSTEM

The gaseous products resulting from the combustion of the refuse pass over the bridge wall at the far end of the primary combustion chamber (away from the charging opening). The gas is immediately forced downward by an air-cooled refractory baffle into the secondary combustion chamber which is shown in Figure 2-7. Another oil burner, also manufactured by Hauck, is located in the sidewall of the bridge wall-baffle passage, spaced relatively close to the bridge wall. While this afterburner is primarily intended as a means of recovering energy from waste oil, it also serves to achieve complete combustion of the gases from the primary chamber. The mixed products of combustion from the primary chamber and the afterburner are detained in the large refractory-lined secondary combustion chamber for an average of 3 seconds to ensure completion of the combustion process and to allow settling out of the large particulate.

BOILER

From the secondary chamber the combustion products enter an Eclipse waste heat recovery fire tube boiler as shown in Figure 2-8. It has a surface area of 4426 ft^2 and can accommodate gas temperatures of 1600° to 500°F at 4000 standard cubic feet per minute (SCFM). Its capacity is 14,184 lb/hr of 150 psi saturated steam.

AIR POLLUTION CONTROL SYSTEM

The furnace gases, having been cooled to approximately 500°F in passing through the waste heat boiler, flow through a multiple cyclone dust collector as shown in Figure 2-9 for the removal of fine dust particles or particulate. The dust collector comprises a battery of 40 individual collector elements arranged for parallel flow so that one-fortieth of the total gas flow passes through each collector. The dust is discharged periodically through a damper into an ash container as shown in Figure 2-10.

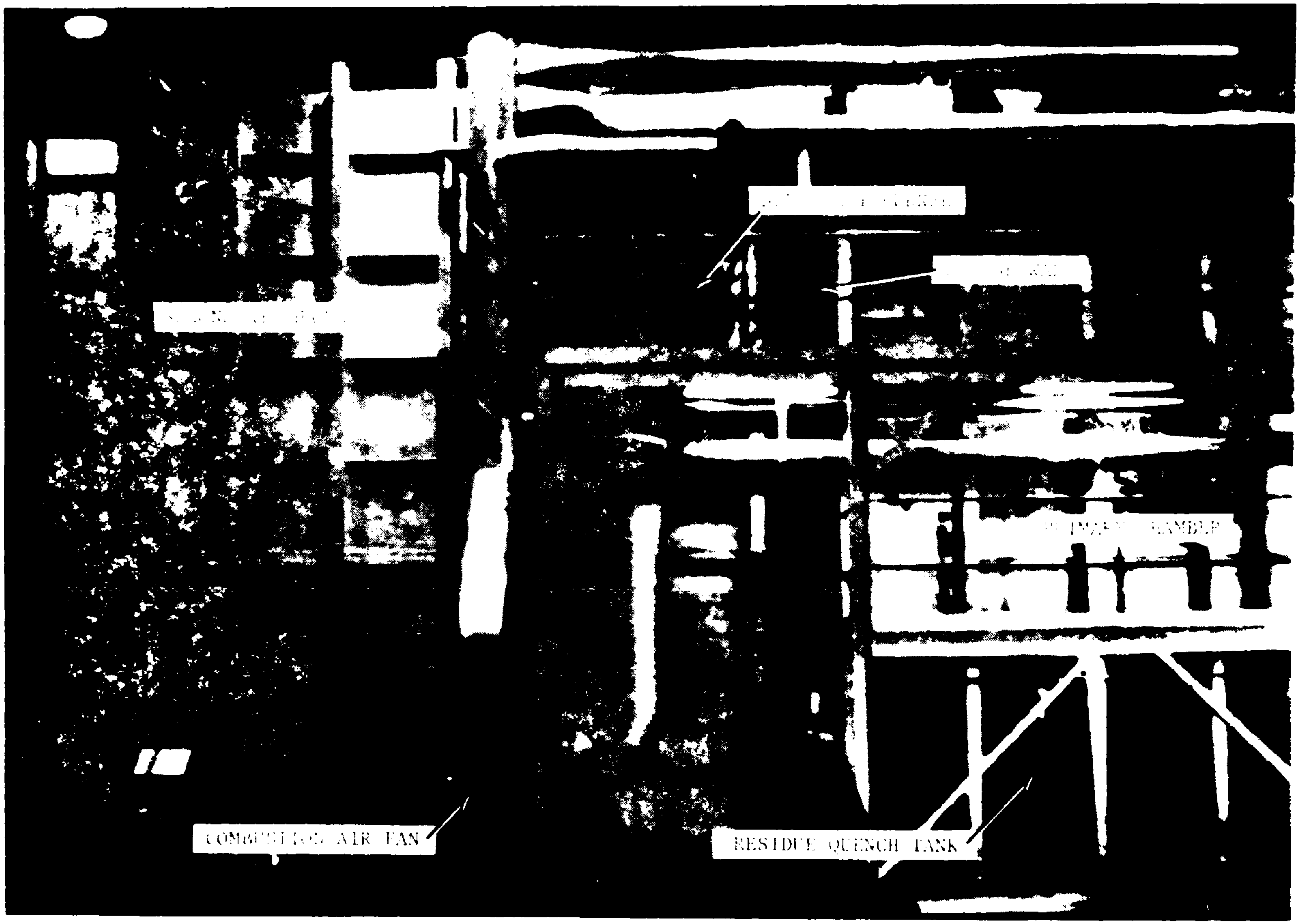


Figure 2-7. View of incinerator showing the bridgewall, auxiliary burner, secondary chamber combustion system, dump stack, and duct to the boile

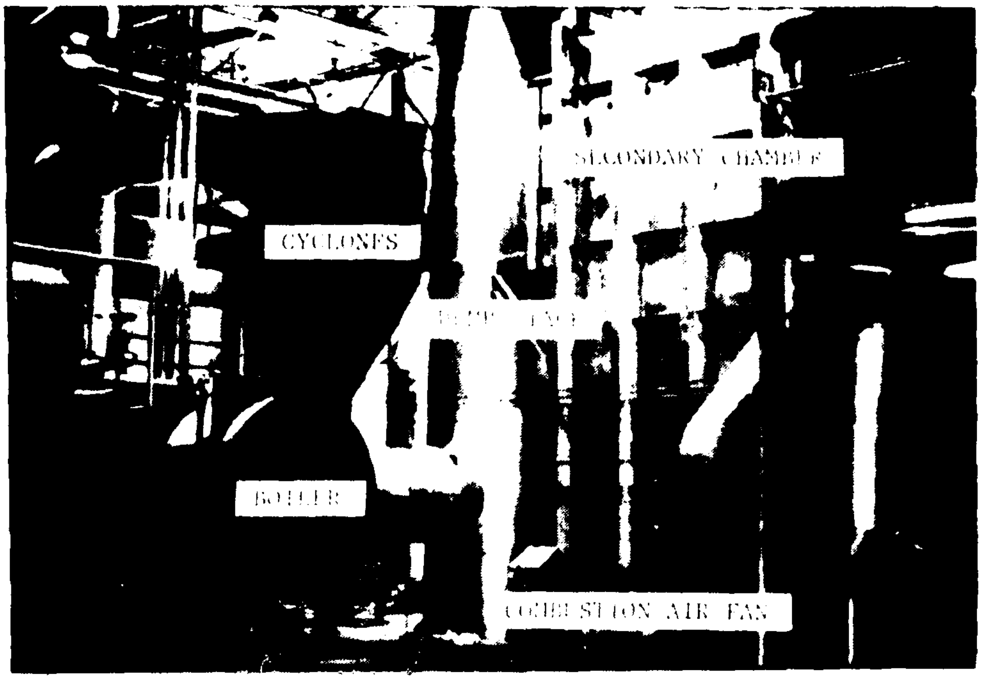


Figure 2-8. [illegible] of waste heat boiler illustrating the interconnecting flue gas duct work.

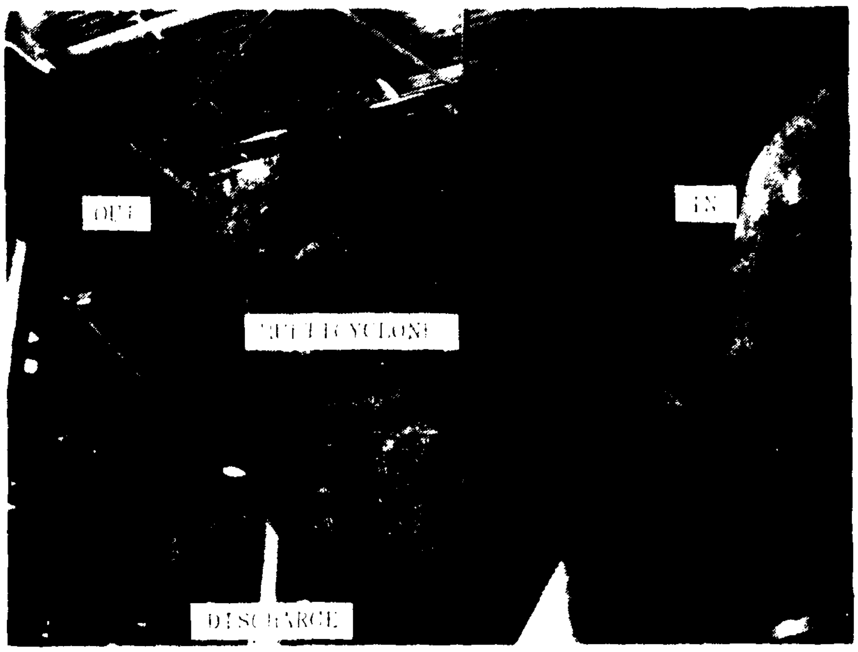


Figure 2-9. Air pollution control system multiple cyclone system.

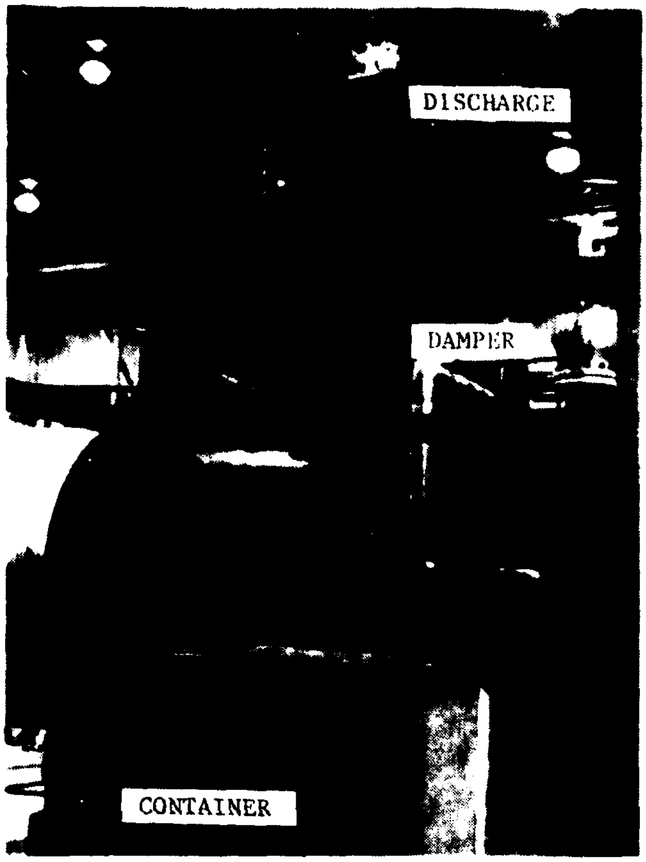


Figure 2-10. Discharge of air pollution control device into fly ash container.

BREECHING AND INDUCED DRAFT SYSTEM

Flue gases exiting the dust collector next pass through an insulated steel breeching to the induced draft (ID) fan. This fan, shown in Figure 2-11, provides the draft needed to overcome the flow resistance of the dust collector, waste heat boiler, and the various interconnecting breechings and maintains a negative pressure in the primary furnace. The pressure in the system is controlled by modulating the damper in the discharge of the ID fan.

STACK SYSTEM

The discharge from the ID fan is connected to the main stack through a short breeching. The main stack is free standing, 75 ft high, and is

Figure 2-11. View of incineration system induced draft fan.

completely refractory lined (see Figure 2-12). A second refractory-lined stack, a flue gas dump stack, is located between the secondary combustion chamber and the boiler inlet (see Figures 2-7 and 2-13). This dump stack is utilized when there is no need to generate steam or if there is a maintenance problem in the boiler, air pollution control, or fan systems. The dump stack has a cap that is held closed during normal operation and opens when ong of the aforementioned situations occur.

INSTRUMENTATION AND CONTROL

The system is operated from a control room located above the incinerator as shown in Figure 2-5. A view of the entire tipping floor, incinerator, and boiler is possible from the control room. The instrumentation panel shown in Figure 2-14 provides the operator with data concerning chamber temperatures, pressures, and airflow; steam output and pressures; and the amount of solid waste in the clamshell.

Figure 2-12. Location of main stack.

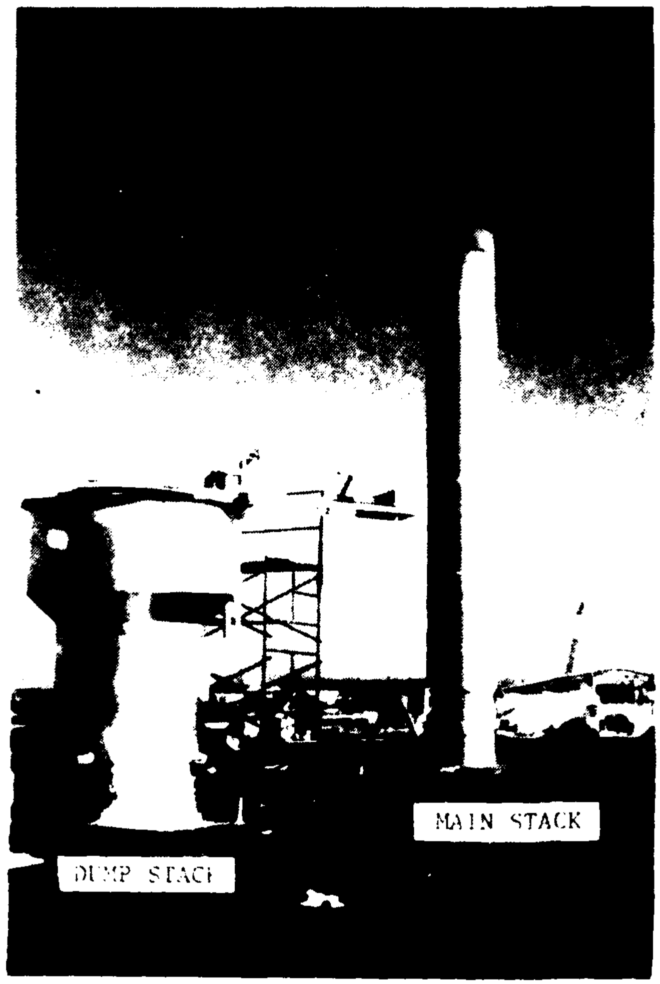


Figure 2-13. View from roof level of dump stack and main stack.

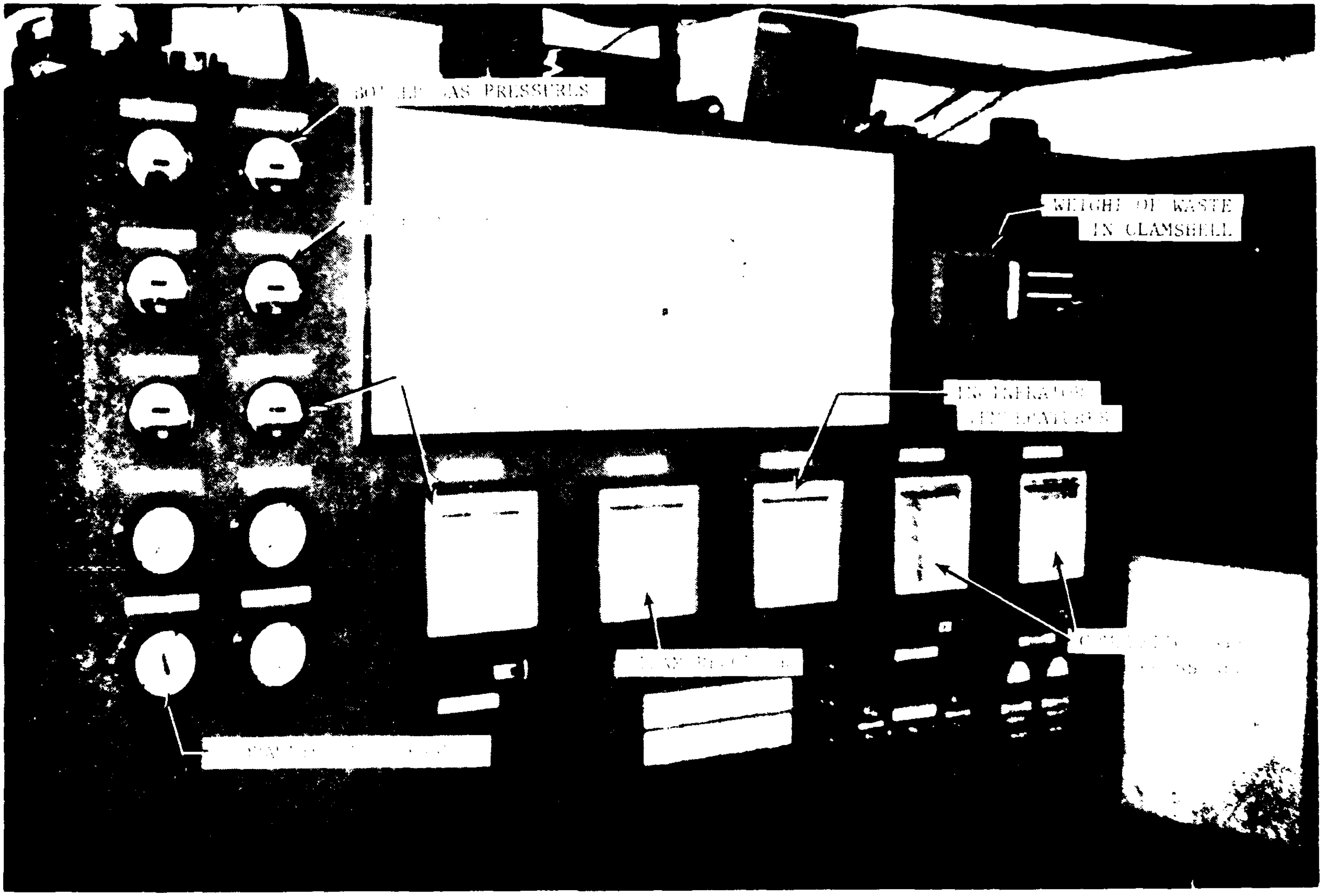


Figure 2-14. Instrumentation panel located in the control room above the incinerator.

SECTION 3

TEST METHODS

INTRODUCTION

Testing at the Naval Station, Mayport, heat recovery incinerator was conducted to provide a detailed technical and environmental evaluation. Six process streams were characterized for this evaluation: solid waste, waste oil, bottom ash, fly ash, flue gas, and steam generated. This section describes in detail the various test methods employed for this characterization and their associated accuracies.

A process flow diagram of the NS, Mayport, HRI is shown in Figure 3-1. Samples and meter readings were taken for subsequent analysis from the sites labeled A through I. In order to generate a heat balance and to determine the thermal efficiency of the HRI, mass flow rates were monitored at sites A through I.

Table 3-1 summarizes all of the elements to be measured or sampled and indicates the sampling schedules, locations, and methodologies. Each of these elements is described in detail in this section.

SOLID WASTE MEASUREMENTS

The solid waste received at the NS Mayport HRI was characterized in terms of its feed rate to the incinerator, composition, moisture content, heating value, and ultimate analysis. The methods and equipment employed for this characterization are described as follows.

Feed Rate

The feed rate of solid waste into the combustion unit was measured by recording the load cell weights of waste delivered into the feed hopper by the overhead crane. Civil Engineering Laboratory personnel accomplished calibration of the load cells by repeated weighings of a known mass of material. The results of these calibrations indicated that the recorded load cell weights are the true weight. The readout of this load cell has a resolution of .01 ton.

Solid Waste Characterization

To analyze the performance of the incinerator, the input waste was characterized in terms of its compositon and moisture content. This task consisted of periodic sampling of the solid waste using the clamshell and

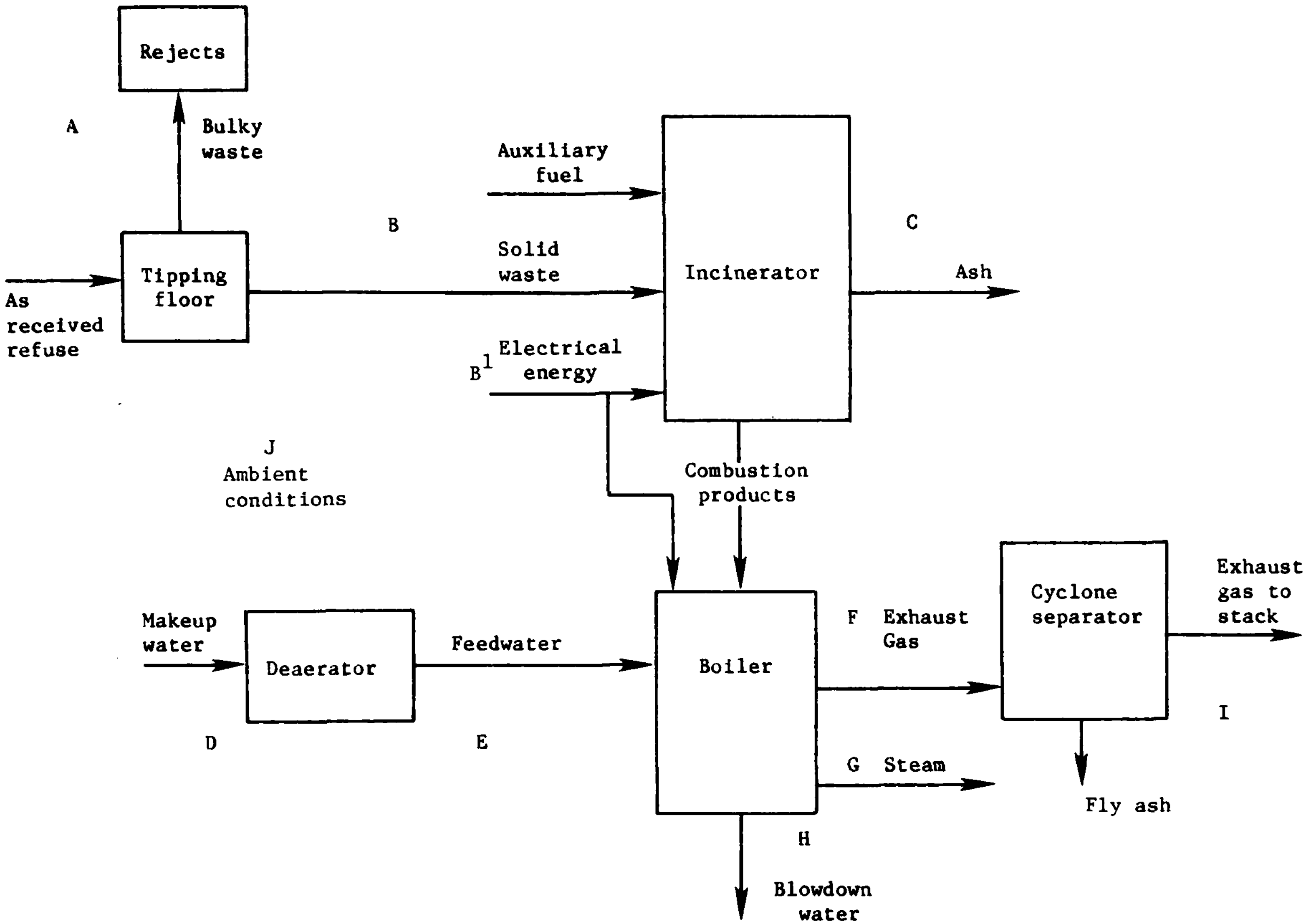


Figure 3-1. NS Mayport heat recovery incinerator sampling locations as described in Table 3-1.

TABLE 3-1. FIELD MEASUREMENTS FOR MAYPORT HRI EVALUATION

Measurement number	Stream sampled	Sample location	Measurement required	Sample size	Frequency	Measurement method
Inputs						
1.	Base waste	A	As-received daily weight total test weight/rate	N.A.	Each truckload	Truck scale
2.		B	Hourly feed rate	N.A.	As charged	Monitor load cell Digital accumulator
3.		A	Characterization	~700 kg/day	Two daily composites	Hand sort
4.		A	Moisture content	1 kg/category	Daily	Drying oven
5.		A	Heating value	1 kg/category	1/wk	ASTM - D271-48
6.		A	Ultimate analysis	1 kg/category	1/wk	ASTM - 3176
7.	Rejects	A	Total daily weight	N.A.	Each load	Truck scale
8.	Front-end loader fuel	A	Daily consumption	N.A.	Daily	Average usage rate
			Heating value	N.A.	N.A.	Published values
9.	Fuel oil	B	Daily consumption	N.A.	Hourly	Flow meter
			Heating value	N.A.	N.A.	Published values
10.	LP gas	B	Daily consumption	N.A.	Hourly	Pressure/calculation
			Heating value	N.A.	N.A.	Published values
11.	Waste oil	B	Daily consumption	N.A.	Hourly	Flow meter
			Heating value	250 cc/tank	1/tank	Bomb calorimeter
			Moisture content	250 cc/tank	1/tank	ASTM - D95-561
12.	Electrical energy	B_1	Daily consumption	N.A.	Daily	Meter reading
13.	Makeup water	D	Quantity	N.A.	Hourly	Flow meter
			Enthalpy	N.A.	Hourly	Temperature-recorder
Output						
14.	Steam	G	Quantity	N.A.	Hourly	Makeup water meter
			Enthalpy	N.A.	3/day	Steam calorimeter
			Pressure	N.A.	Hourly	Bourdon Gauge
			Quantity check	N.A.	Hourly	Steam flow meter
Losses						
15.	Ash	C	Daily generation	N.A.	Each load	Truck scales
			Moisture	1-kg	Daily composite	Drying oven
			Heating value	50 g	Daily	Bomb calorimeter
			Combustibles	50 g	Daily	Muffle furnace
16.	Flue gases	F	Temperature-Boiler outlet	N.A.	Hourly	Temperature recorder
			Moisture	N.A.	Daily	Measured H_2O input
			O_2	N.A.	Continuous	Electro chemical cell
			CO_2	N.A.	Continuous	NDIR
			CO	N.A.	Continuous	NDIR

(continued)

TABLE 3-1. (Continued)

Measurement number	Stream sampled	Sample location	Measurement required	Sample size	Frequency	Measurement method
Losses (continued)						
16.	Flue gases (continued)	F	Mass flow rate	N.A.	Daily	Calculation from stoichiometry
			Specific heat	N.A.	Daily	From chart ASME PTC 4.1
17.	Blowdown	G	Continuous quantity	N.A.	Hourly	Manual measurement
			Intermittent quantity	N.A.	As scheduled	
			Temperature	N.A.	Hourly	Temperature recorder
18.	Cyclone fly ash	I	Quantity	N.A.	As removed	Truck scale
			Metals content	25 g	2/week	ICP analysis
			Leachability	500 g	1/week	EP Toxicity test
			Size distribution	100 g	Daily	Screens balance
			Heat content	25 g	Daily	Bomb calorimeter
19.	Surface radiation and convection	Incinerator/ boiler	Surface temperatures	N.A.	1/week	Surface pyrometer
			Surface dimensions	N.A.	1/week	Plant plans
Emissions						
20.	Stack gases	I	CO_2	N.A.	3/M-5 tests	Orsat
			CO	N.A.	3/M-5 tests	Orsat
			O_2	N.A.	3/M-5 tests	Orsat
			CO_2	N.A.	Continuous	Horiba NDIR/recorder
	Flue gases	F	SO_x	N.A.	Continuous	SCC
			NO_x	N.A.	Continuous	SCC
	Stack gases	I	Cl	N.A.	1/day	Impinger water titration
			Volume/velocity	N.A.	2/day	Pitot tube traverse
			Temperature	N.A.	2/day	Method 5
			Condensibles	>300 mℓ	1/day	Impinger water analysis
			Particulate emission	>60 SCF	2/day	EPA Method 5
			Particulate sizing	N.A.	1/day	Inertial cascade impactor
			Particulate metals	N.A.	1/day	ICP analysis, M-5 filters
Operational data			Temperature	N.A.	Continuously	Temperature recorder
21.	Ambient conditions	J	Barometric pressure	N.A.	2/day	Barometer
			Relative humidity	N.A.	2/day	Sling psychrometer
			Primary chamber temperature	N.A.	Continuously	Temperature recorder
22.	Incinerator	B	Secondary chamber temperature	N.A.	Continuously	Temperature recorder

overhead crane followed by hand sorting of the sample into 13 categories: cardboard, paper, garden trimmings, food, wood, ferrous metals, aluminum, other nonferrous metals, glass, plastics, textiles, inerts, and fines. Samples of each waste category were then dried daily to determine the moisture contents.

The following procedures were used for solid waste composition characterization:

1. Each truck was weighed both full and empty to determine the waste delivered to the tipping floor. Weights were recorded on a digital readout Fairbanks truck scale, accurate to ±50 lb (see Figure 3-2).

2. All of the truck weights for 1 day were added to determine the daily total of gross waste.

3. The large and noncombustible rejects were weighed and subtracted from the gross waste to determine the net weight supplied to the pit.

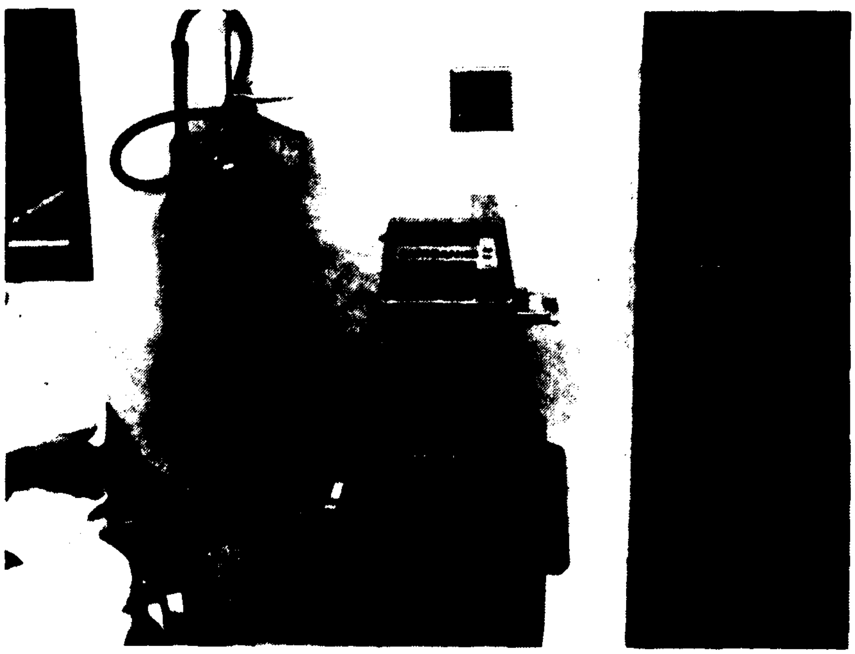


Figure 3-2. Fairbanks digital readout scale.

4. The clamshell device was used to mix the waste and then to pick up a bucket load of the mixed waste and deposit it on the floor of the test area.

5. Step 4 was repeated several times each day, forming two large samples on the floor by the end of the day.

6. After all the waste for a given day had been sampled, the clamshell was used to thoroughly mix the samples prior to reducing the volume by the coning and quarting techniques.

7. Large items and boxes were broken up manually to ensure that the selected samples were representative of the waste.

8. This process was continued until the sample sizes were reduced to approximately 1000 to 2500 lb each.

9. Each of the samples, representative of the waste for that day, was then hand sorted into the 13 categories previously identified (see Figure 3-3).

Figure 3-3. Solid waste hand sorting technique.

10. The total weight of each category in each of the samples was determined. The overall accuracy of the composition determination is within ±5 percent.

11. Representative samples (1 kg) of each category (obtained by coning and quartering) were then weighed, dried overnight at 103°C, and weighed again to determine the moisture level. The accuracy of this procedure has been determined to be within 1 percent of the mean moisture level.

Heating Value

The higher heating value (HHV) and lower heating value (LHV) of the as-fired solid waste were determined by applying published values* of chemical energy contents of each category to the total weight of each category fired. As a cross-check for this procedure, samples were submitted for laboratory analysis. The results of the laboratory analyses are compared with the textbook values. Differences and their resulting impact on the analyses are discussed.

A 1-kg portion of each dried combustible component (cardboard, paper, organics, food, wood, plastics, textiles, and fines) was obtained from each of the hand sorted samples and returned to the SYSTECH (Xenia) laboratory. These samples were then milled with a Thomas Wiley No. 4 mill until the particles passed through a 5-mesh screen. The milled samples were combined by categories and a 0.5-kg representative sample of each category was subjected to heating value analysis by bomb calorimetry as per ASTM D2015. This method has a stated precision limit of ±100 Btu/lb, dry basis.

Ultimate Analysis

The ultimate analysis of the as-fired fuel was determined by applying published values* of ultimate analyses of each category to the total weight of each category fired. As a cross-check for this procedure, samples were also submitted for laboratory analysis. The results of the laboratory analyses are compared with the textbook values. Differences and their resulting impact on the analyses are discussed.

Each of the samples prepared and submitted for heating value analysis was also subjected to ultimate analysis for carbon, hydrogen, oxygen, nitrogen, sulfur, chlorine, and ash by application of ASTM Method 3176. The overall precision for this analytical procedures is within 1 percent.

WASTE OIL

The waste oil combusted at the NS, Mayport, HRI was characterized in terms of its feed rate, heating value, and moisture content. This section describes the test methods employed and their associated accuracies.

---

* The values used are those given in Combustion, "Physical-Chemical Character of Municipal Refuse," by Elmer P. Kaiser, P.E., February 1977.

Feed Rate

The feed rate of waste oil from the storage tanks was measured by two Trident flow meters (see Figure 3-4). These meters were calibrated by weighing timed samples of waste oil flowing through the meters and comparing these weights to the recorded meter readings. The accuracy of both meters was within 1 percent.

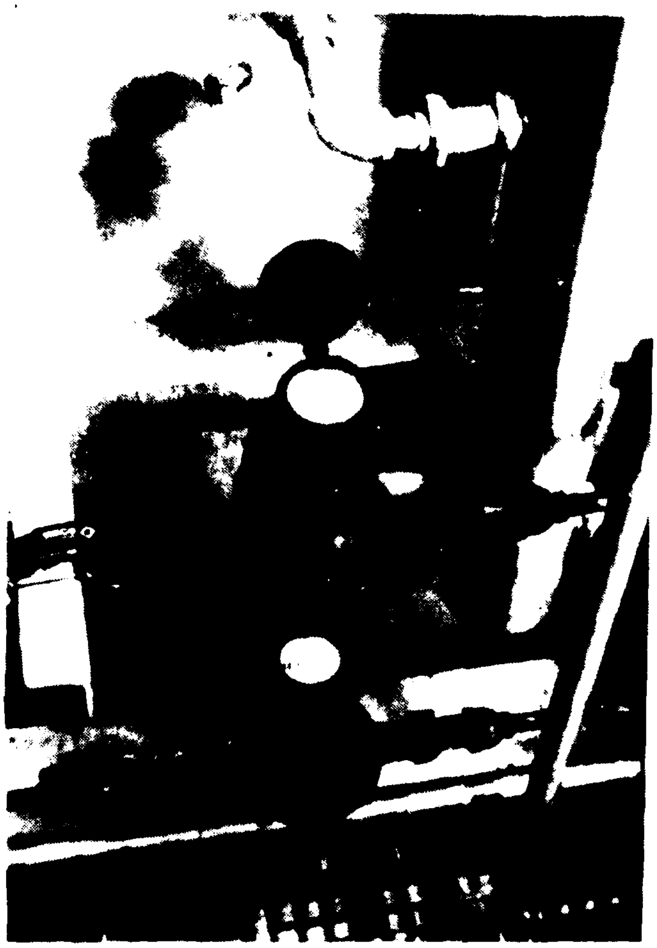


Figure 3-4. Waste oil Trident flow meters.

Sampling

Waste oil samples were taken by using a "sampling thief" designed to obtain a representative sample as per ASTM Method D270-557. Samples were obtained from both storage tanks and stored in clean glass jars.

Analyses

Waste oil samples were analyzed for moisture content by the ASTM D96-68, API Standard 2542 centrifugation method. Duplicate analyses by this procedure have been found to agree within 0.2 mℓ.

Waste oil samples were submitted to Gilbert Laboratories for determination of the heat of combustion by bomb calorimetry as per ASTM D240. Duplicate analyses by this procedure have been found to agree within 55 Btu/lb.

ASH MEASUREMENTS

Bottom ash generated at the NS, Mayport, HRI during the test period was examined for the following parameters: moisture, combustibles content, heating value, total output rate, and extraction procedure (EP) toxicity. Cyclone catch ash was examined for size distribution, heating value, metals content, and EP toxicity. The methods used for these analyses and their associated accuracies are outlined as follows.

Bottom Ash Sampling

Every 2 hours during the 3 test days, 2-kg ash samples were taken from the ash container. The daily samples were combined and then coned and quartered to make representative daily samples of 2 kg. These daily samples were then used to determine the daily ash moisture content, the energy contents of unburned combustibles, and the dry ash weight.

Bottom Ash Moisture and Combustibles

The daily samples were sealed in plastic bags and weighed. The samples were then transported to SYSTECH's (Xenia) laboratory. There the samples were reweighed, dried overnight in a laboratory oven at 103°C, and reweighed to determine moisture content. The accuracy of this measurement has been determined to be within 1 percent. The dried samples were then hand separated into the recognizable fractions of glass, ferrous and inerts, and combustibles. The remaining portion consisting of small pieces of char, ash, and unrecognizable material was classified as fines and combined with the combustibles. Each component of each sample was then weighed. To determine the amount of unburned combustibles in the fines and combustible fractions, samples were milled and then placed in a tared, desiccated crucible and set in the muffle furnace. The furnace was taken up to 700°C, held at that temperature for 1 hour, and then turned off. Once cooled, the samples were removed, desiccated, and reweighed. The material remaining was considered to be ash, and the lost mass (corrected for the mass removed during sorting) was taken to be combustibles. This method is a variation of ASTM D3174 for which the precision of results is stated to be within 1 percent.

Bottom Ash Heating Value

The heating value of the bottom ash was determined from the measured combustibles content by application of the heating value of carbon

(14,500 Btu/lb) to the combustible materials in the ash as per ASME PTC 4.1. Heating values determined by this method have been found to agree within less than one standard deviation of the mean heating value as determined by bomb calorimetry.

Cyclone Ash Sampling

It was anticipated that samples of cyclone ash would be taken from the collection dumpster at the end of each test day. Because of the small amount of material trapped by the cyclones (approximately 20 lb) only one sample was taken at the end of the test period. This sample was obtained by coning and quartering the entire contents of the dumpster into a laboratory sample of approximately 1 kg.

Cyclone Ash Sizing

Cyclone ash particle size distribution was accomplished by placing the ash in a set of standard sieves having a particle capture range from 500 to 45 microns and shaking on a sieve shaker for 2 minutes. The sieves were then rotated 180°, shaken for another 2 minutes, rotated a final 180°, and shaken for an additional 2 minutes. The weight of particulate matter trapped by each sieve was then determined gravimetrically.

Cyclone Ash Heating Value

The heating value of the cyclone ash was determined using identical procedures to that described for the bottom ash.

Cyclone Ash Metals

A 1-g sample of cyclone ash was subjected to Parr bomb digestion in Ultrex® nitric acid. This sample was then analyzed by Inductively Coupled Plasma (ICP) emission techniques for the presence of 25 metals. Detection limits and precision data for this technique are included in the Appendix.

Extraction Procedure Toxicity

Samples of bottom ash were taken for EP toxicity analysis by coning and quartering a sample from the ash storage container. Two samples (500-mℓ volume each) were collected three times daily with a stainless steel scoop and put into tared 500-mℓ amber glass jars. One set of samples was weighed and stored in the dark until the end of the test day at which time they were composited into a smaller sample. The other set of samples was weighed on tared drying pans to the nearest 1 gram and dried overnight in a low temperature (30°C) drying oven to obtain the air dried moisture content.

Bottom ash samples were then composited by weight at the end of each daily test period. This compositing was accomplished by transferring a weighed 500-g aliquot from each of the three daily samples into a 2-ℓ amber glass bottle. These daily composite samples were then composited into single composite samples for the test period by transferring 500 grams from each into a 2-ℓ amber glass bottle.

One 1500-g sample of cyclone particulate was taken for EP toxicity analysis by coning and quartering a sample from the cyclone ash dumpster. The sample was weighed and stored in the dark until analyzed.

The bottom ash and cyclone ash samples were then subjected to EP toxicity analysis as per Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Office of Solid Waste, U.S. EPA, May 1980. Detection limits and precision data for the analyses conducted are included in the Appendix.

Total Ash Output

The total amount of cyclone ash removed at the end of the test was weighed. Each filled container of bottom ash was weighed prior to landfill disposal. These weights were recorded to determine the total daily amount of wet ash generated. The daily generation rates were totaled at the conclusion of the 3-day test period to determine the total weight of wet ash generated. The daily amount of dry ash generated was calculated by subtracting the determined daily moisture content from the daily total of wet ash generated. All weights were obtained by weighing the containers on a Fairbanks Scale, Model No. 50-3508, with a stated accuracy of ±50 lb.

FLUE GAS MEASUREMENTS

The flue gas was sampled at the boiler outlet before entering the cyclones to determine its composition and temperature. These measurements were taken both as a means to characterize the combustion gases and as necessary data to calculate the mass and energy flow in the flue gas.

Composition Sampling

The composition of the flue gases at the boiler outlet was monitored continuously for CO_2, CO, SO_x, NO_x, and O_2. The gases were drawn from the boiler outlet and conditioned prior to entering the analytical instruments by removing the particulate matter and water vapor via a sintered metal filter and an ice bath condensing chamber.

CO_2 and CO--

Carbon dioxide and carbon monoxide levels in the flue gas were monitored during the daily test periods with Beckman Model 864 Infrared Analyzers. Within each analyzer two equal energy infrared beams are directed through two optical cells, i.e., a flow-through sample cell and a sealed reference cell. Solid state electronic circuitry continuously measures the difference between the amount of infrared energy absorbed in the two cells. This difference is a measure of the concentration of the component of interest in the sample stream. Manufacturer's specifications on these instruments indicate an accuracy of 1 percent of full scale with zero and span drifts of ±1 percent of full scale for 24 hours. The electronic response time for deflection of 90 percent of scale is 0.5 seconds. The response time due to sample transportation from the stack to the instrument was approximately 1 to 3 minutes.

O_2, SO_x, and NO_x--

The remaining gaseous emissions of interest were monitored on a Theta Sensor Source Monitor, Series 7213, Model 1940. This instrument will monitor O_2, SO_x, and NO_x simultaneously through the use of three separate electrochemical transducers connected in series. The principle of operation of this instrument is based on the combined use of a semipermeable membrane and selective oxidation-reduction reactions within completely sealed electrochemical transducers. The electrical signals generated by these transducers are directly proportional to the concentrations of the gases being monitored. The response is linear over the entire analytical range. The accuracy stated by the manufacturer is ± 2 percent of full scale. The stated zero drift for NO_x and SO_x is 2 percent for 14 hours with a span drift of 1 percent for 24 hours. The oxygen cell is stated to have a 0.5 percent zero drift for 24 hours with a span drift of 1 percent. The NO_x and SO_x cells give a 90 percent deflection within 60 seconds while the oxygen cell responds in less than 20 seconds. In all cases instrument response is considerably better than the delay due to the sample transfer from the stack to the instrument.

Calibration--

After the instruments were set up at the field test site, and every 12 hours during the 78-hr test period, each instrument was subjected to a multipoint calibration consisting of a zero grade nitrogen (N_2), a calibration gas which is roughly equivalent to a 90 percent of scale reading, and no less than one calibration gas in the mid scale range. This multipoint calibration established the validity of the instrument response curves and also served as an operational check of the instrument. A morning and evening zero span calibration procedure was employed to verify that no significant changes in instrument response occurred during the test period. The instrument response obtained on these morning and evening calibrations was averaged to obtain a daily calibration correction factor which was applied to the data recorded during that day for each instrument.

Data Recording and Reporting

The electrical outputs from the continuous monitoring instruments were channeled to a Leeds & Northrup SPEEDO-MAX® W multipoint strip chart recorder with a six channel capability. The trace for each instrument was analyzed for maximum reading, minimum reading, and the mean of all 15-min points during the test period for that day.

Temperature Measurements

The exhaust gas temperature was measured continuously at the boiler outlet location using a calibrated Type-K thermocouple and continuously recorded on the multipoint recorder. The accuracy of this thermocouple has been measured at ± 1 percent. Readings were taken on an hourly basis as part of the hourly plant tour.

Mass Flow Determination

The mass flow of gases at the boiler outlet was calculated from the flue gas composition and fuel ultimate analysis.

MASS AND ENERGY FLOW MEASUREMENTS

Mass and energy flow measurements were made to permit the calculation of the daily and weekly mass balance and thermal efficiency and the weekly heat balance of the NS, Mayport, HRI. The thermal efficiency is a measurement of the ratio of useful energy outputs to total energy inputs.

Energy input consists of the chemical energy in the solid waste; the auxiliary fuels (liquified petroleum [LP] gas, waste oil, and fuel oil); and front-end loader fuel. Also included in the energy input is the sensible heat in the makeup water and combustion air and the electrical energy used by the system. Energy output of the system is the energy content of the steam generated.

A heat balance requires measurement of the energy losses. Energy loss is that portion of the energy input which does not become useful energy output. Such loss includes the following: unburnt combustibles in the residue, enthalpy of the blowdown water, sensible heat in the stack gases, and radiative and convective losses from the surface of the unit.

The energy inputs were determined as follows:

1. Solid waste: The daily total mass and energy content of waste delivered was determined as described in the Solid Waste Measurement section.

2. Auxiliary Fuel:

    a. Waste oil: The daily and weekly consumption and energy content were determined from waste oil flow meters and laboratory analyses of waste oil samples.

    b. Fuel oil: The daily and weekly consumptions were to be determined by recording hourly readings of the fuel oil totalizing flow meter. The type of fuel oil was to be identified and its corresponding energy value provided from published data. However, since no fuel oil was used, these calculations were not made.

    c. Liquified petroleum gas: The daily and weekly consumptions were to be determined by recording the LP gas gauge reading at 24-hr intervals. The LP gas energy value was to be provided from published data. However, since a negligible amount of LP gas was used, these calculations were not made.

    d. Front-end loader fuel: Consumption was determined from the average usage rate per hour provided by plant personnel.

3. The total electrical energy supplied to the facility on a daily basis and for the total test period was determined by recording the voltage and amperage of the supply line and calculating the

equivalent heat input to a generating station required to produce that amount of electrical energy.

The useful energy output in the form of steam was determined as follows:

1. For balance purposes, the daily and weekly test period quantity of steam produced was calculated from the quantity of feedwater input minus the water lost in blowdowns. Feedwater was measured by a Trident flow meter (see Figure 3-5). The meter was calibrated by weighing a timed flow of water from the meter and comparing this value to the meter reading. The accuracy of the meter was found to be ± 1 percent.

2. The energy value of the generated steam was determined three times daily by using a Cal Research steam calorimeter connected directly to a steam supply line and by noting the steam pressure on the Bourdon gauge.

Figure 3-5. Trident feedwater meters.

The energy losses used to calculate the heat balance were determined as follows:

1. Ash: The total quantity of fly ash removed from the exhaust gases and the residue removed from the primary chamber over the test period were determined by weighing the respective fly ash and residue collection containers daily. The energy values were determined as described earlier.

2. Blowdown water: Energy lost in the blowdown water was computed as the sum of the water lost in the continuous and intermittent blowdowns, with the energy equivalent as a function of blowdown water temperatures, as recorded by continuous thermocouple readings (accuracy ± 1 percent).

   The amount of water lost in continuous and intermittent blowdowns was determined as follows:

   a. The daily continuous blowdown was determined from the totalizing flow meter reading recorded on an hourly basis. The accuracy of this flow meter was determined by a timed weight comparison to be within 1 percent.

   b. The intermittent blowdown was determined by multiplying the number of blowdowns during the test period by an average value for the quantity of water per blowdown. The average value of the quantity of water per blowdown was determined experimentally.

3. Stack gases: The energy lost in the stack gases was determined from the total mass of gas emitted and its corresponding specific heat and temperature differential above ambient.

   Since moisture in the flue gas is exhausted as superheated steam, the latent heat of vaporization of the moisture in the fuel and the moisture formed in hydrogen combustion was accounted as losses.

4 & 5. Energy lost by convection and radiation was calculated according to ASME PTC 33. Energy losses unaccounted for were calculated by the difference between total energy input and useful energy output plus accounted losses.

STACK EMISSION MEASUREMENTS

Stack emissions were sampled from the stack access ports at roof level. This flue gas was analyzed for velocity, temperature, moisture, particulate loading, particulate sizing, particulate metals concentration, and gas composition.

Particle Sampling

The particle loading, gas velocity, and moisture content were determined using a standard EPA Method 5 train and "S"-type pitot (see Figure 3-6). The procedures used were as prescribed in CFR 40, Methods 1, 2, 3, 4, and 5. The stack gas composition (O_2, CO_2, CO) was determined by Orsat analysis during the Method 5 testing. After the particulate filter weights were recorded, the filters were returned to the SYSTECH (Xenia) laboratory for analysis of the metals in the particles collected.

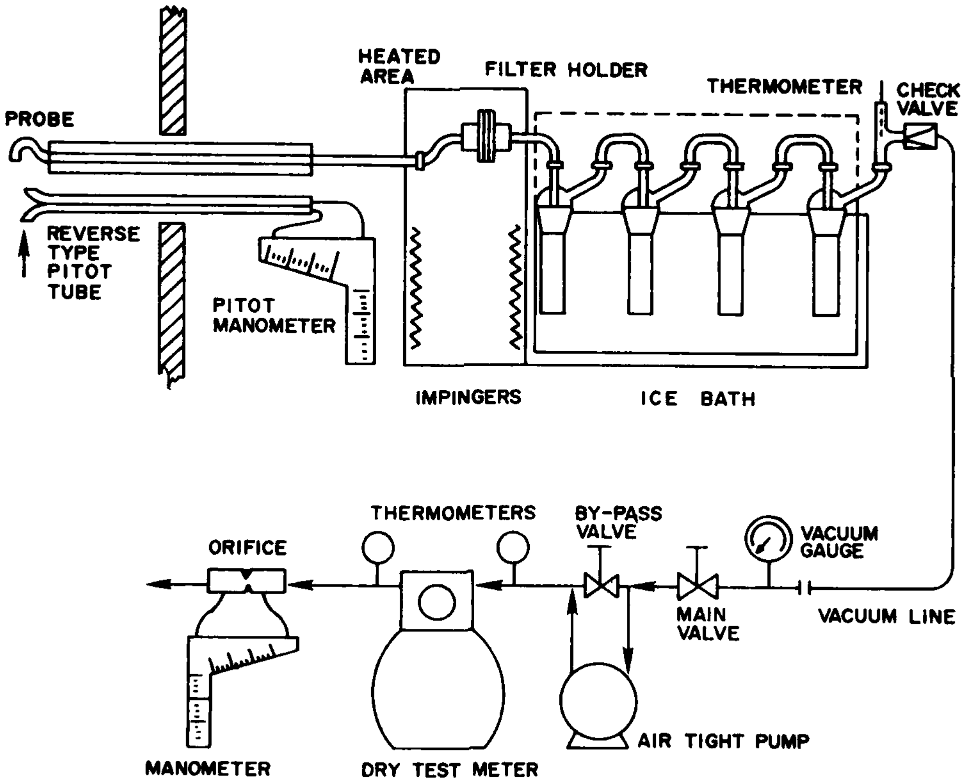


Figure 3-6. Method 5 secondary chamber exiting particulate sampling assembly.

An MRI Inertial Cascade Impactor (see Figure 3-7) was used to determine stack particle size. Seven collection stages yielded seven size fractions spanning "greater than 30" to "less than 0.4 microns." The mass of material collected was weighed on an analytical balance accurate to within 0.1 mg. The particle sample was collected and sized aerodynamically in the stack at isokinetic conditions.

Chlorides

With each Method 5 run the chloride concentration in the stack gas was determined. This was accomplished by analyzing the hydrogen peroxide solution from the first impinger of the Method 5 train according to EPA Method 325.3 Storet No. 00940. The precision of this method as relative standard deviation is approximately 3 percent.

Composition Sampling

The composition of the stack flue gases emitted to the atmosphere was monitored continuously for CO_2. The gases were drawn from the stack and conditioned prior to entering the analytical instrument by removing the particulate matter and water vapor via a sintered metal filter and an ice bath condensing chamber. In addition, the composition of stack gases was measured three times during each Method 5 run by Orsat.

CO_2--

Carbon dioxide levels in the flue gas were monitored during the daily test periods with a Horiba portable NDIR analyzer. The stated precision of this instrument is ± 2 percent of full scale.

Calibration--

After the instrument was set up at the field test site, and every 12 hours during the test period, the instrument was subjected to a multipoint calibration consisting of a zero gas nitrogen (N_2), a calibration gas which is roughly equivalent to a 90 percent of scale reading, and no less than one calibration gas in the mid scale range. This multipoint calibration established the validity of the instrument response curve and also served as an operational check of the instrument. A morning and evening zero span calibration procedure was employed to verify that no significant changes in instrument response occurred during the test period. The instrument response obtained on these morning and evening calibrations was averaged to obtain a daily calibration correction factor which was applied to the data recorded during that day for the instrument.

Data Recording and Reporting

The electrical output from the continuous monitoring instrument was channeled to a Leeds & Northrup SPEEDO-MAX® W multipoint strip chart recorder with a six channel capability. The trace for this instrument was analyzed for maximum reading, minimum reading, and the mean of all 15-min points during the test period for that day.

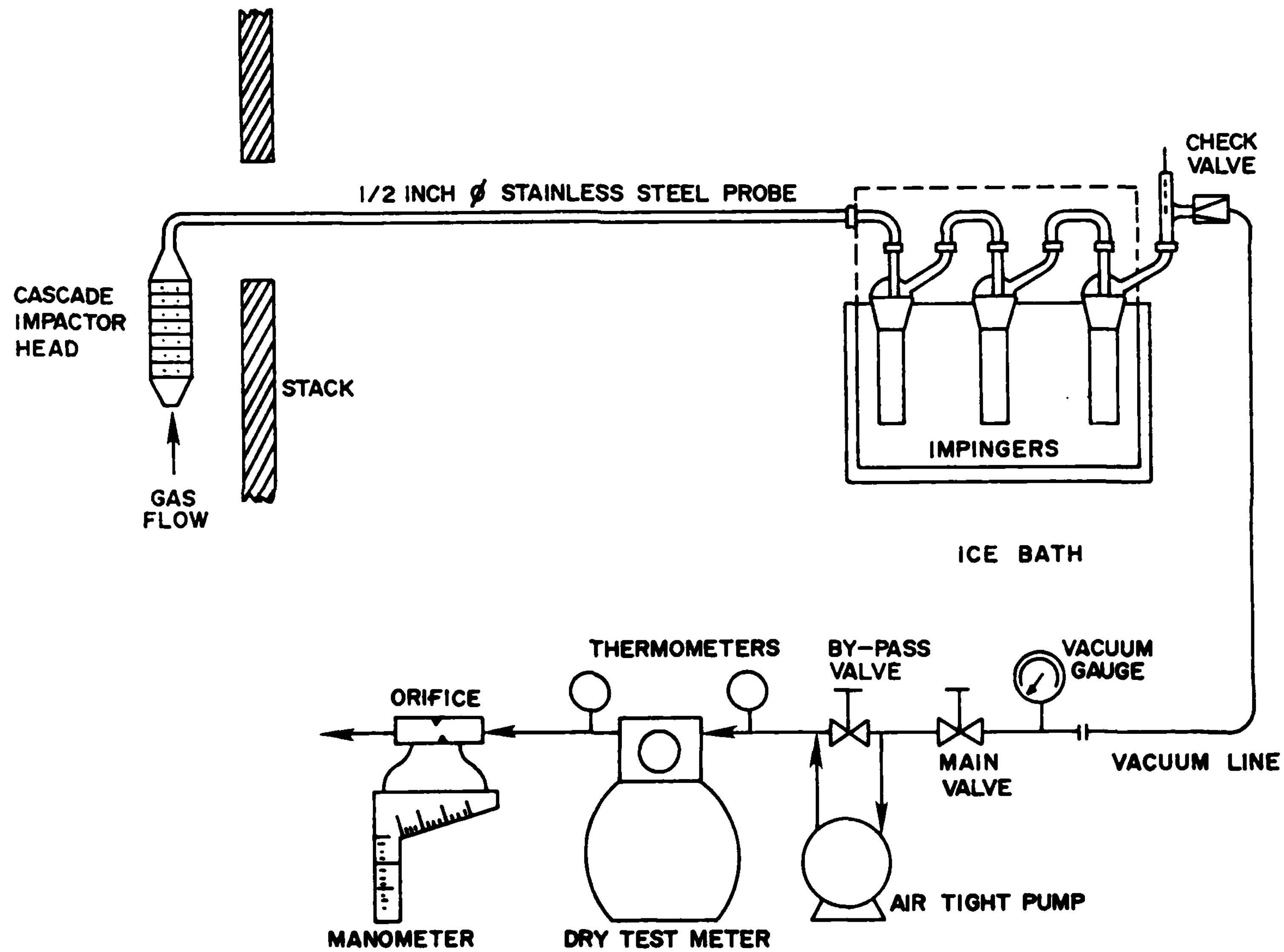


Figure 3-7. Schematic of seven-stage cascade impactor.

Particulate Metals

One Method 5 filter from each test day was digested in a Parr bomb with Ultrex® nitric acid and composited into a single analysis sample. A blank filter was also digested by the same procedure. The acid digests were then analyzed by Inductively Coupled Plasma emission techniques for 25 metals. Detection limits and precision data for this technique are included in the Appendix.

Mass Flow Determination

The mass flow of material from the stack was calculated as per CFR 40 methods. The calculations used are indicated on the appropriate data sheets. The accuracy of the measurements determined by this method are within 19 percent of the true mean at a 95 percent confidence level.

TEST CONDITION MEASUREMENTS

Ambient temperature, barometric pressure, and relative humidity were measured twice daily for use in the mass and energy balances. Ambient temperature was measured continuously by a Type-K thermocouple accurate to within 1 percent. Barometric pressure was measured with a standard test barometer accurate to within 0.01 in Hg. Humidity measurements were made with a Bacharach sling psychrometer.

In addition, the following operating conditions were recorded by the following methods during the hourly plant tour for heat balance and informational purposes:

1. Steam pressure - direct gauge reading

2. Steam temperature - direct gauge reading

3. Temperatures -

   a. feedwater
   b. blowdown water
   c. makeup water
   d. ambient air
   e. boiler exit gas

   Thermocouples connected directly to multipoint recorder. Hourly data points were recorded on a master hourly data sheet.

4. Atmospheric pressure - barometer

5. Boiler feedwater - totalizing flow meter

6. Steam production - totalizing flow meter

7. Primary chamber and afterburner characteristics

   Temperatures - Type-K thermocouple with data continuously recorded on a multipoint recorder

8. Fluid flows -

a. continuous blowdown
b. LP gas
c. fuel oil
d. waste oil

flow meters

SECTION 4

RESULTS

SOLID WASTE CHARACTERISTICS

The composition of the solid waste received during the November and December test periods is shown in Table 4-1. Since no moisture analysis was performed in December and because the weather was similar for the November and December test periods, the November moisture data was applied to the December composition. The results of this moisture determination are shown on Table 4-1. The field data and calculations of the solid waste characterization are included in the Appendix.

Ultimate analysis of the refuse was determined by applying a textbook ultimate analysis for each category to the waste composition results from the month of December. This resulting ultimate analysis is shown on Table 4-2 and is the one that will be used in the analysis. Calculations and standard values used in computing the ultimate analysis are shown in the Appendix. Laboratory ultimate analyses were also performed on samples of the refuse from the manual sorts. The results of these laboratory analyses are shown in comparison to the textbook values on Table 4-3. The carbon, hydrogen, and oxygen contents of the prevalent categories are similar for laboratory and textbook values. The differences in other elements and categories have a negligible effect on the mass and energy balances.

In a procedure similar to that used to determine ultimate analyses, the solid waste heating value was computed by applying standard category heating values to waste composition. This calculation is presented in the Appendix. On an as-received basis, the refuse had a higher heating value of 5134 Btu/lb and a lower heating value of 4502 Btu/lb. Heating values and moisture content of the refuse are shown on Table 4-4.

To verify the standard heating values used in the heating value computation, bomb calorimeter tests were performed on samples of the refuse. Results of the calorimeter tests are shown on Table 4-5 along with the standard heating values used in the computations. These laboratory results verify the standard values used.

AUXILIARY FUEL CHARACTERISTICS

Since no fresh fuel oil was burned and a negligible amount of LP gas was used to maintain burner pilot lights, the fuel oil and LP gas were not analyzed. A large amount of waste oil was burned as auxiliary fuel for the incineration process. Therefore, the waste oil was sampled and analyzed. The

TABLE 4-1. WASTE COMPOSITION RESULTS - WEEKLY AVERAGE
(Average of daily results, As-received basis)

Category	November Weight (%)	November H_2O (%)	December Weight (%)
Cardboard	15.6	22.0	15.2
Other paper	24.7	28.9	29.5
Food waste	4.2	69.0	5.8
Yard waste	4.3	34.2	5.9
Wood	5.0	18.9	3.1
Ferrous	4.9	8.5	5.3
Aluminum	1.8	14.6	1.0
Other metals	0.6	0.6	1.4
Glass	4.0	1.4	4.4
Plastics	8.3	6.9	10.4
Textiles	6.4	14.2	6.6
Inerts	2.3	16.8	1.5
Fines	18.1	40.9	9.9

heating value, moisture, and density of the waste oil were determined by laboratory analysis. Results of these analyses are reported in Table 4-6. An estimated ultimate analysis of the waste oil was used in the mass balance calculation. This estimated ultimate analysis shown in Table 4-6 is for a typical fuel oil regardless of grade.

TABLE 4-2. REFUSE ULTIMATE ANALYSIS WEEKLY AVERAGE (Dry weight basis)

Carbon	38.69
Hydrogen	5.12
Oxygen	27.17
Nitrogen	0.81
Chlorine	0.75
Sulfur	0.22
Inerts	27.18

ASH CHARACTERISTICS

Bottom Ash

Laboratory analysis of bottom ash samples collected during the December test indicate a good ash quality. Results of these analyses are shown in Table 4-7. The quenched ash was about one-third moisture by weight. The average combustible content of the ash was 3.1 percent (4.6 percent dry weight basis), indicating that the tested incinerator produced acceptable burnout of the ash. The data and calculations of the ash analysis are included in the Appendix.

EP toxicity testing was performed on the bottom ash samples. Results of the test are shown in Table 4-8. It should be noted that the leachate from the bottom ash samples contained no contaminants in excess of the maximum allowable in 40 CRF 261.24. Therefore, this bottom ash is not considered a hazardous waste.

Cyclone Ash

Although only 20 lb of fly ash was collected by the cyclone collection, this fly ash was sampled and analyzed. Table 4-9 shows the results of this fly ash analysis.

After the December test 47 lb of ash were removed from the boiler tubes and 560 lb of slag were removed from the secondary combustion chamber. For mass and energy balance purposes this ash and slag were assumed to have the same characteristics as the cyclone fly ash.

TABLE 4-3. ULTIMATE ANALYSIS OF REFUSE
Published (P) - Laboratory (L)
(Percent dry weight basis)*

Category	Carbon		Hydrogen		Oxygen		Nitrogen		Chlorine		Sulfur		Inerts	
	P	L	P	L	P	L	P	L	P	L	P	L	P	L
Cardboard	46.0	44.9	6.3	5.7	44.3	44.5	.14	.03	.15	.13	.29	.29	2.8	4.56
Other paper	42.1	43.2	5.8	5.7	38.8	41.9	.40	.17	.79	.34	.25	<.02	11.8	9.07
Food waste	44.8	48.1	6.4	6.9	32.1	34.5	2.8	2.7	.95	.91	.15	<.01	12.7	7.68
Yard waste	42.3	46.5	5.3	5.4	31.9	40.4	1.6	0.70	.24	.16	.27	.36	18.3	6.78
Wood	49.0	50.0	6.0	5.9	41.1	41.4	.28	0.59	.11	.003	.08	<.02	3.3	2.09
Plastics	66.4	77.8	9.2	11.3	9.5	5.7	1.0	0.15	3.5	4.09	.34	<.02	10.1	5.05
Textiles	49.6	50.5	6.7	5.7	36.1	37.7	4.1	1.25	.36	.26	.37	<.02	2.6	4.85
Fines	20.0	25.5	2.5	3.3	16.2	19.5	.66	1.12	.48	.61	.20	2.50	59.9	50.1

* Kaiser, Elmer R., P.E., "Physical-Chemical Character of Municipal Refuse," Combustion Magazine, February 1977, pp. 26-28.

TABLE 4-4. HEATING VALUES AND MOISTURE CONTENT OF DECEMBER REFUSE

Basis	HHV (Btu/lb)	LHV (Btu/lb)	Moisture (%)
As-received	5,134	4,502	25.1
Dry weight	6,854	6,011	---

TABLE 4-5. REFUSE HIGHER HEATING VALUES
(Dry weight basis)

Category	Standard HHV* (Btu/lb)	Measured HHV (Btu/lb)
Cardboard	7,791	7,862
Other paper	7,429	7,420
Food waste	8,162	9,042
Yard waste	7,282	8,006
Wood	8,253	8,423
Plastics	13,630	15,827
Textiles	8,793	8,452
Fines	3,457	4,568

* Kaiser, Elmer R., P.E., "Physical-Chemical Character of Municipal Refuse," Combustion Magazine, February 1977, pp. 26-28.

TABLE 4-6. WASTE OIL PROPERTIES

	November		December	
	Tank 1	Tank 2	Tank 1	Tank 2
HHV (Btu/lb)	19,704	19,782	19,425	19,753
LHV (Btu/lb)	18,559	18,637	18,280	18,608
Density (lb/gal)	6.890	6.890	6.826	6.841
Moisture (%)	-----	----	<0.2	<0.2

Ultimate analysis (estimated)

	(%)
Carbon	86
Hydrogen	12
Oxygen	--
Nitrogen	--
Chlorine	--
Sulfur	0.5
Inerts	--

Results of the sizing analysis performed on the cyclone fly ash are shown in Figure 4-1. As the figure indicates, 95 percent of the fly ash collected by the cyclone is greater than 46 μm in size. This size cutoff occurred because multiclones are not efficient particle-collecting devices when particle sizes are below 20 to 30 μm. The typically small particle size of incinerator particulates makes a cyclone dust collector an inefficient emissions control device.

The metals content of cyclone particulates was determined, and the results are shown in Table 4-10. The results of EP toxicity testing performed on leachate of the cyclone fly ash are shown in Table 4-11. The levels of cadmium and lead found in the cyclone fly ash leachate are above the maximum allowable levels; therefore, cyclone fly ash alone could be considered a hazardous waste. If the small amount of cyclone fly ash generated by this plant was mixed with the large amount of bottom ash generated, the resulting mixture would probably give acceptable results in an EP toxicity test. However, if a more efficient dust collector was installed on this system, the resulting fly ash stream could cause a disposal problem.

TABLE 4-7. BOTTOM ASH REPORT

BOTTOM ASH REPORT
(Wet weight basis)

Day	Monday	Tuesday	Wednesday*	Thursday	Friday		Weekly average
Date	12/08/80	12/09/80	12/10/80				
Moisture (percent)	31.3	33.3	33.0				32.6
Combustibles (percent) wet	2.3	4.3	2.7				3.1
Heating value (Btu/lb)	333	624	391				450
Wet output (lb)	5,660	15,540	35,320			Total	56,520
						Total dry ash output (lb)†	38,094

* Includes output on Thursday to 0600 hr

† Dry output $= \frac{100 - \text{Average moisture percent}}{100} \times$ Wet output

Total residue heat loss = Average heating value × Total wet output = $\underline{25.4 \times 10^6}$ Btu

Average dry weight heating value $= \frac{100 \times \text{Average wet weight heating value}}{(100 - \text{Average moisture percent})} = \underline{\quad 667 \quad}$ Btu/lb

TABLE 4-8. EP TOXICITY RESULTS

Bottom Ash Leachate

Contaminant	Bottom ash (mg/ℓ)	Maximum allowable* (mg/ℓ)
Arsenic	0.122	5.0
Barium	1.60	100.0
Cadmium	0.135	1.0
Lead	4.170	5.0
Mercury	0.0025	0.2
Selenium	0.020	1.0
Silver	0.085	5.0
Endrin	<0.005	0.02
Lindane	<0.001	0.4
Methoxychlor	<0.010	10.0
Toxaphene	<0.010	0.5
2, 4-D	<0.002	10.0
2, 4, 5-TP	<0.002	1.0

* As specified in 40 CFR 261.24.

TABLE 4-9. CYCLONE FLY ASH REPORT

Date December 1980 Location NS, Mayport, FL

Fly ash gross weight	N/A	lb
Ash container tare weight	N/A	lb
Net fly ash weight	20	lb
Average combustible content	0.93	percent
Heating value	135	Btu/lb
Heat lost in fly ash	2706	Btu*

* Heat lost = fly ash gross weight × heating value.

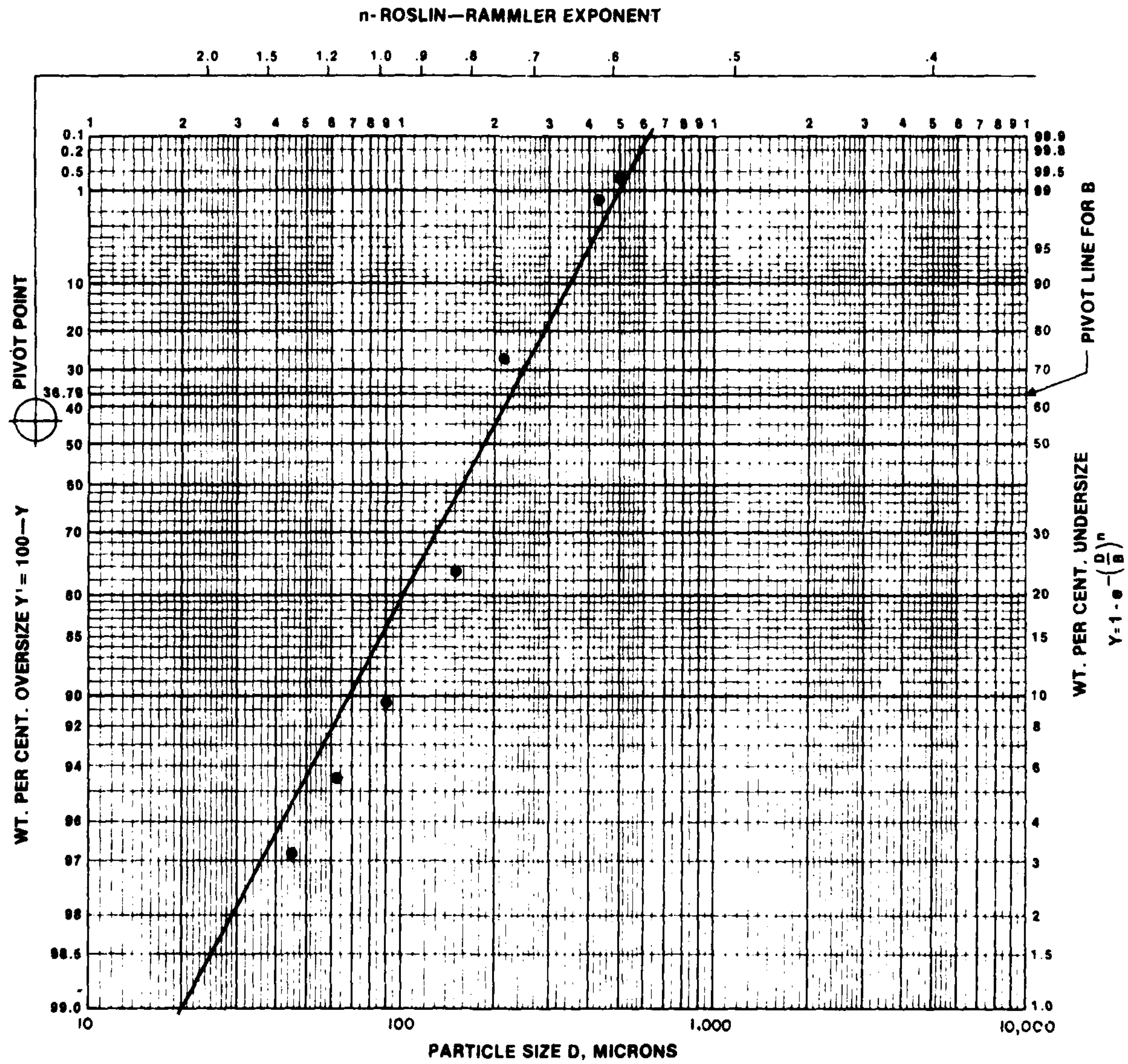


Figure 4-1. Cyclone particulate size distribution.

TABLE 4-10. CYCLONE PARTICULATE METALS

Metal	mg/g
Ag	<0.015
Al	29.0
Ba	1.22
Be	0.001
B	0.260
Ca	62.9
Cd	0.111
Co	0.080
Cr	0.255
Cu	1.18
Fe	25.7
Mg	8.01
Mn	3.19
Mo	0.083
Na	12.8
Ni	0.376
Pb	2.31
P	4.74
Sb	0.183
Si	0.062
Sn	0.125
Sr	0.213
Ti	1.54
V	0.447
Zn	6.51

TABLE 4-11. EP TOXICITY RESULTS

Cyclone Ash Leachate

Contaminant	Fly ash (cyclone) (mg/ℓ)	Maximum allowable* (mg/ℓ)
Arsenic	0.058	5.0
Barium	0.775	100.0
Cadmium	2.35	1.0
Chromium	0.590	5.0
Lead	8.195	5.0
Mercury	0.0016	0.2
Selenium	0.018	1.0
Silver	0.105	5.0
Endrin	<0.005	0.02
Lindane	<0.001	0.4
Methoxychlor	<0.010	10.0
Toxaphene	<0.010	0.5
2, 4-D	<0.002	10.0
2, 4, 5-TP	<0.002	1.0

* As specified in 40 CFR 261.24.

MASS AND ENERGY BALANCES

Inputs

During the 78-hr test in December, 80 tons of solid waste were processed. This processing rate calculates to 1.03 TPH. Daily and total mass and energy inputs from solid waste are shown on Table 4-12. All waste burned during the test was collected on base; no municipal waste was received during the test. Waste oil was burned at a rate of .17 lb/lb of solid waste (49 gal/ton). Thirty-nine percent of the fuel energy input was contributed by waste oil. Daily and total mass and energy inputs from waste oil are shown in Table 4-13. Field data and calculations used to compute the mass and energy inputs for solid waste and waste oil are presented in the Appendix.

TABLE 4-12. SOLID WASTE MASS AND ENERGY INPUT

Day	Date	Base waste weight (lb)	Heat input* (10^6 Btu)
M	12/08/80	51,520	264.5
T	12/09/80	47,980	246.3
W†	12/10/80	60,460	310.4
Totals		159,960	821.2

* Weekly refuse higher heating value (as-received) was 5134 Btu/lb.

† Through 6 a.m. Thursday.

TABLE 4-13. WASTE OIL MASS AND ENERGY INPUT

Day	Date	Volume input (gal)	Mass input (lb)	Heat input (10^6 Btu)	Tank No.
M	12/08/80	1,395	9,611	190.14	2
T	12/09/80	1,093	7,531	148.97	2
W*	12/10/80	1,444	9,949	196.04	1
Totals		3,932	27,091	535.15	

* Through 6 a.m. Thursday.

No fuel oil was used during the test, and the small amount of LP gas used was neglected in this analysis. To account for all significant energy input into the plant, electrical energy supplied to the facility was measured and diesel fuel used by the front-end loader was estimated. The energy inputs from these two sources are shown in Table 4-14. Data and calculations for these estimates are included in the Appendix.

Air input was determined stoichiometrically using fuel ultimate analysis and flue gas composition data. The ultimate analysis of the solid waste and the waste oil had to be combined in proportion to the mass input of each to form a composite ultimate analysis for each day. Since the composite ultimate analysis showed little change from day to day, the 3 days were combined to form one average ultimate analysis which was applied in all subsequent calculations. Table 4-15 contains the composite ultimate analysis used in the calculations. Daily composite analyses are presented in the Appendix.

Flue gas composition was measured at the boiler outlet. On Monday, December 8, and part of December 9, 1980, a leak in the flue gas sampling system diluted the sample and caused erroneous readings on the continuous flue gas monitoring system. This leak was corrected by noon on Tuesday, December 9, 1980. Continuous monitor readings taken after correction of the leak deviated less than 2.5 percent of scale for the duration of the test. Therefore, the flue gas composition determinations for the last 42 hours of testing (i.e., after the leak was fixed) were averaged and applied to the entire 78-hr test. The flue gas composition used in air and flue gas flow calculations is also shown in Table 4-15. Results of the continuous monitor readings are in the Appendix.

The procedure for determining the air to fuel ratio is in the Appendix. The result of this determination is 13.21 lb of air per pound of combined fuel. Table 4-16 shows the fuel and air inputs for each day.

TABLE 4-14. ANCILLARY ENERGY USAGE

Day	Date	Hours	Diesel fuel (10^6 Btu)	Electrical energy (10^6 Btu)
M	12/08/80	24	1.62	47.16
T	12/09/80	24	1.62	47.16
W*	12/10/80	30	2.03	58.95
Total			5.27	153.27

* Through 6 a.m. Thursday.

TABLE 4-15. AVERAGE FUEL AND FLUE GAS ANALYSIS

Composite Ultimate Analysis*	
Element	%
C	37.3
H	5.0
O	17.4
N	0.7
Cl	0.5
S	0.2
I	17.5
H_2O	21.4
Average Boiler Outlet Flue Gas Composition (Dry Basis)	
CO_2 (%)	7.5
O_2 (%)	12.7
CO (ppm)	58
Excess air (%)	150

* Composite of average solid waste and waste oil analyses.

TABLE 4-16. AIR AND FUEL INPUTS

Day	Date	Total fuel input* (lb)	Total air input (lb)
M	12/08/80	61,131	807,540
T	12/09/80	55,511	733,300
W†	12/10/80	70,409	930,103
Total		187,051	2,470,900

* Fuel oil and base waste.

† Through 6 a.m. Thursday.

Outputs

Energy output from the incinerator system was in the form of saturated steam. Average production and conditions of the steam are shown in Table 4-17. Steam production calculations are presented in the Appendix. The steam had an average quality of 98.7 percent; therefore, the steam separator appeared to be functioning well.

Losses

Bottom ash output is shown in Table 4-18. The ash output increased each day of the test because of retention of ash and start-up effects. Heat losses in the bottom ash were minimal as would be expected for the good quality of ash.

Fly ash was removed only once at the end of the test. The heating value of the fly ash collected in the cyclone was applied to the ash removed from the boiler, the slag removed from the secondary combustion chamber, and the fly ash emitted from the stack. Fly ash emitted as particulate was quantified by the EPA Method 5 test at an average of 17.1 lb/hr. For mass and energy balance purposes, the fly ash losses were divided among the 3 days proportional to the operating hours for each day. Table 4-19 shows the fly ash losses. As the table indicates, the chemical energy remaining in the fly ash was low.

Sensible heat losses in the flue gas are shown in Table 4-20. Calculations of these sensible heat losses are shown in the Appendix.

Blowdown and leakage losses are shown in Table 4-21. These losses were calculated from the recorded meter readings of continuous blowdown water usage as shown in the Appendix and from an estimate of the amount of water used in each intermittent blowdown multiplied by the number of intermittent blowdown periods. The enthalpies were determined from the measured temperatures of the blowdown and makeup waters.

TABLE 4-17. STEAM PRODUCTION

Day	Monday 8 Dec.	Tuesday 9 Dec.	Wednesday* 10 Dec.	Total
Steam output (10^3 lb)	199	191	260	650
Steam enthalpy (Btu/lb)	1185	1187	1188	---
Makeup water enthalpy (Btu/lb)	48	48	48	---
Energy output (10^6 Btu)	226	218	296	740
Steam pressure (psig)	149	158	160	---
Steam quality (percent dry)	98.7	98.6	98.7	---

* Through 6 a.m. Thursday.

TABLE 4-18. BOTTOM ASH LOSSES

Date	Monday 12/08/80	Tuesday 12/09/80	Wednesday* 12/10/80	Total
Wet output (lb)	5,660	15,540	35,320	56,520
Heating value (Btu/lb)	333	624	391	----
Heat loss (10^6 Btu)	1.885	9.697	13.810	25.392

* Through 6 a.m. Thursday.

TABLE 4-19. FLY ASH LOSSES

Date	Monday 12/08/80	Tuesday 12/09/80	Wednesday* 12/10/80	Total
Operating time (hrs)	24	24	30	
Fly ash weight (lb)	603	603	753	1,959†
Net loss§ (10^3 Btu)	81.4	81.4	101.6	264.4

* Through 6 a.m. Thursday.

† Based on
20 lb - Cyclone catch
47 lb - Boiler cleanout
560 lb - Furnace slag
1332 lb - Particulate (17.1 lb/hr)

§ Cyclone fly ash heating value 135 Btu/lb.

TABLE 4-20. FLUE GAS SENSIBLE HEAT LOSSES

Date	Monday 12/08/80	Tuesday 12/09/80	Wednesday* 12/10/80	Total
Flue gas weight (10^3 lb)	865	778	976	2,619
Sensible heat (10^6 Btu)	126	116	144	386

* Through 6 a.m. Thursday.

TABLE 4-21. BOILER LOSSES

Date	Monday 12/08/80	Tuesday 12/09/80	Wednesday* 12/10/80	Total
Continuous blowdown				
(10^3 lb)	19.173	17.756	17.256	55.601
(Btu/lb)	75.98	77.98	77.98	77.31
Intermittent blowdown				
(10^3 lb)	23.966	25.008	31.260	80.234
(Btu/lb)	75.98	77.98	77.98	77.31
Makeup water (Btu/lb)	48	48	48	48
Heat loss (10^6 Btu)	1.207	1.282	1.455	3.980

* Through 6 a.m. Thursday.

Surface radiation and convection losses were determined from the temperatures and surface areas of the various units of the systems and their corresponding heat transfer coefficients as defined in ASME PTC 33 for large incinerators. Table 4-22 shows the losses incurred per hour at each system unit. The overall loss by radiation and convection for the 78-hr test period was 89.7×10^6 Btu.

Mass and Energy Balance Sheet

Table 4-23 shows the overall mass and energy balance sheet for the December 1980 test. The mass inputs included were base waste, waste oil, output air, and makeup water. Over the 78-hr test, the mass input was 3443.79×10^3 lb. The mass outputs included steam, flue gas, residue, blowdown, and fly ash. The total mass output measured was 3463.28×10^3 lb. The output mass exceeded the input by less than 1 percent which is well within the measurement error.

The total energy input corresponding to the mass inputs was 1356.4×10^6 Btu. The measured output energy plus energy losses was 1245.4×10^6 Btu, leaving 111×10^6 Btu unaccounted for as miscellaneous losses.

Energy Recovery Efficiency

Energy recovery efficiency is defined the same as boiler efficiency according to ASME PTC 4.1. This efficiency is the ratio of energy recovered as steam to the total energy input. Boiler efficiency was calculated for

TABLE 4-22. RADIATION/CONVECTION LOSSES

System unit	Surface area (ft^2)	Average temperature (°F)	Ambient temperature (°F)	Heat loss (10^3 Btu/hr)
Primary chamber	1182.5	175	80	244.9
Secondary chamber	1629.2	221	80	578.9
Stack below duct	212.6	190	80	53.6
Duct	103.1	260	80	52.0
Breeching from stack to boiler	148.9	241	80	63.8
Stack to roof	1223.5	145	80	156.7
Total system	---	---	---	1149.9

each of the 3 test days by the input-output method. The heat balance method and the input-output method were both used to calculate boiler efficiency for the entire 78-hr test period. Results of these efficiency calculations are shown in Table 4-24. These boiler efficiency calculations include the chemical energy heat inputs of the solid waste, waste oil, and front-end loader fuel. Also the chemical energy required to generate the electrical energy used by the plant is included as an input. If the front-end loader fuel and electrical energy inputs are neglected, the input-output efficiency becomes 54.5 percent.

Overall incinerator efficiency was also calculated. Incinerator efficiency is defined in ASME PTC 33. This efficiency is an expression of the incinerator effectiveness at converting chemical energy into sensible heat. The calculations were carried out by the heat balance method where all chemical energy in the bottom ash, fly ash, and flue gas are considered losses. Incinerator efficiency was calculated to be 98.1 percent.

NOVEMBER MASS AND ENERGY BALANCE

Table 4-25 shows the mass and energy balance sheet for the 67-hr test period in November 1980, during which waste oil only was burned. The mass inputs for this period were waste oil, input air, and makeup water. The total input mass was 2868.41×10^3 lb. Mass outputs and losses during this period were steam and flue gas with a total output of 2869.66×10^3 lb.

TABLE 4-23. MASS AND ENERGY BALANCE SHEET

Date December 1980		Mass (10^3 lb)		Energy (10^6 Btu)	
Inputs					
Base waste [EN_{bw}]		159.96		821.2	
Municipal waste [EN_{MSW}]		---		---	
Waste oils [EN_{wo}]		27.09		535.2	
Air input		2470.90		---*	
Makeup water		785.84		---*	
Electricity [EN_{el}]		---		(153)†	
Loader fuel [EN_{lf}]		---		(5.3)†	
	Total	3443.79	Total	1356.4	[EN_{in}]
Outputs					
Steam [EN_{out}]		650.00			
			Total	740.0	[EN_{out}]
Losses					
Flue gas [EN_{stack}]		2619.00		386.0	
Residue [EN_{ash}]		56.52		25.4	
Blowdown [EN_{bd}]		135.8		4.0	
Fly ash [EN_{fa}]		1.96		0.3	
Radiative/convective [EN_{RC}]		---		89.7	
Miscellaneous losses		---		111.0	
	Total	2813.28	Total	616.4	[EN_{lost}]

* Removed from outputs.

† Not included in balance calculation.

TABLE 4-24. BOILER EFFICIENCY

	Monday 12/08/80	Tuesday 12/09/80	Wednesday 12/10/80	Overall (I/P-O/P method)
Inputs (10^6 Btu)				
Solid waste	264.5	246.3	310.4	821.2
Waste oil	190.1	149.0	196.0	535.1
Electricity	47.2	47.2	58.9	153.3
Loader fuel	1.6	1.6	2.0	5.3
Steam outputs (10^6 Btu)	226	218	296	740
Efficiency (percent)	45	49	52	49

NOTE: Overall efficiency by heat balance method = 56 percent.

The output mass during this period exceeded input mass by less than .01 percent, well within measurement error.

The total energy input corresponding to the mass input during this period was 970.17×10^6 Btu. The total measured output energy and energy losses were 903.17×10^6 Btu, leaving 67.00×10^6 Btu unaccounted for. It is suspected that a large part of this unmeasured energy loss can be traced to the leakage of hot gases through the dump stack. Boiler efficiency for the November period when waste oil only was burned was 63 percent by the input-output method.

STACK EMISSIONS

Table 4-26 and the particulate summary data sheets (see the Appendix) illustrate the maximum, average, and minimum concentrations of emissions measured at the stack. The CO_2 concentration of the stack gases as measured by the continuous NDIR monitor averaged 5.1 percent, with a maximum of 11.6 and a minimum of 0.4. Since it is suspected that the minimum reading represents a momentary leak in the sample line, a more accurate estimate of the variability of CO_2 concentration can be obtained from the calculated standard deviation of the mean which was 1.0 percent. Corresponding Orsat measurements showed an average CO_2 concentration of 5.3 percent, with a maximum of 6.6 and a minimum of 4.0. Orsat analysis also indicated an average O_2 concentration at the stack of 13.8 percent, with a maximum of 15.7 and a minimum of 11.8. The Orsat measurement did not indicate the presence of measurable CO concentrations. The flue gas velocities and temperatures

TABLE 4-25. MASS AND ENERGY BALANCE SHEET

Date November 1980		Mass (10^3 lb)		Energy (10^6 Btu)
Inputs				
Base waste [EN_{bw}]		---		---
Municipal waste [EN_{MSW}]		---		---
Waste oils [EN_{wo}]		49.06		970.17
Air input		2177.07		---*
Makeup water		642.28		---*
Electricity [EN_{el}]		---		(131.65)†
Loader fuel [EN_{lf}]				---
	Total	2868.41	Total	970.17 [EN_{in}]
Outputs				
Steam [EN_{out}]		541.00		
			Total	614.04 [EN_{out}]
Losses				
Flue gas [EN_{stack}]		2226.38		209.04
Residue [EN_{ash}]		---		---
Blowdown [EN_{bd}]		102.28		3.07
Fly ash [EN_{fa}]		---		---
Radiative/convective [EN_{RC}]		---		77.02
Miscellaneous losses		---		67.00
	Total	2328.66	Total	356.13 [EN_{lost}]

* Removed from outputs.

† Not included in balance calculation.

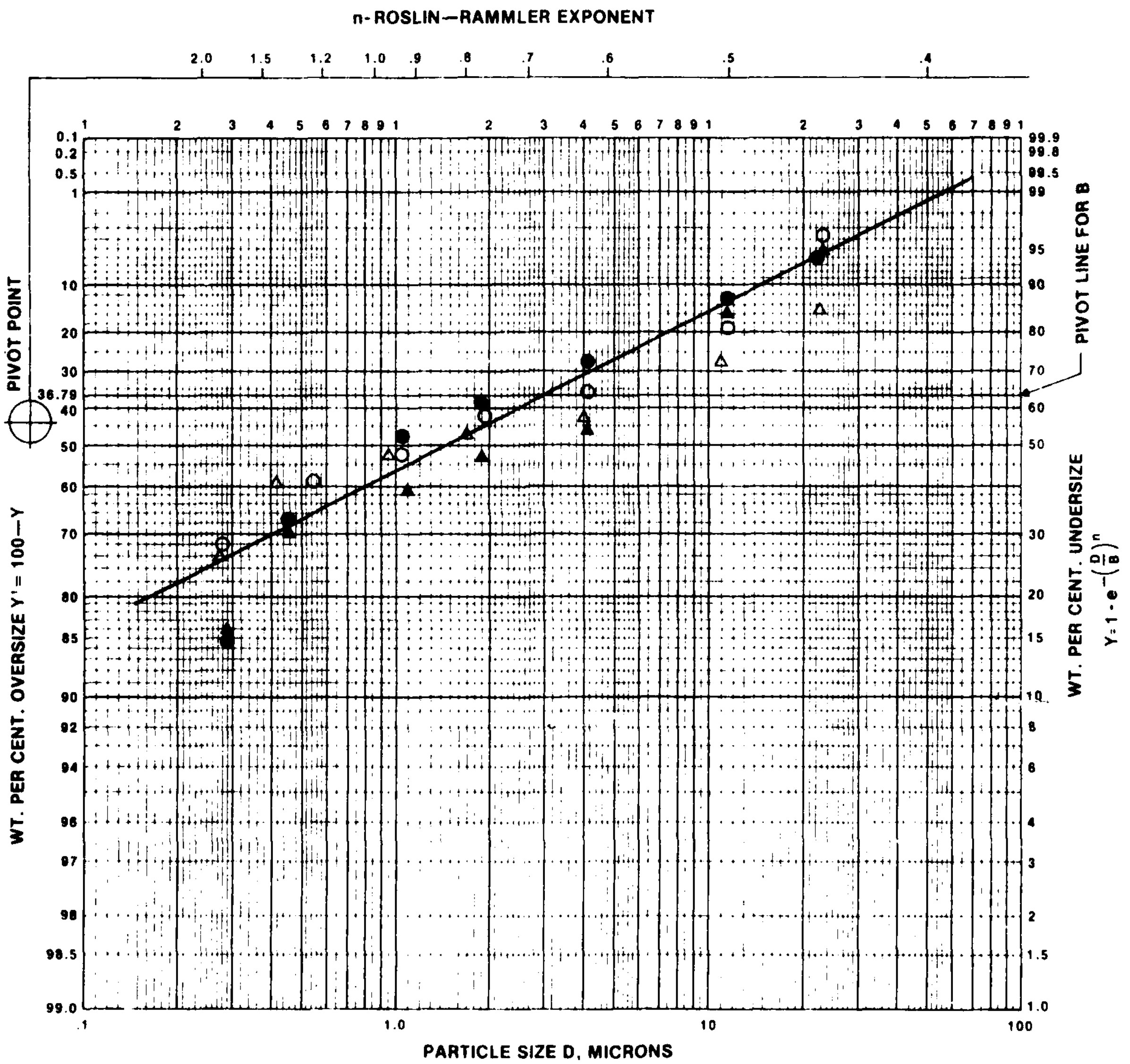
TABLE 4-26. STACK EMISSIONS CONCENTRATIONS

Parameter	Maximum	Average	Minimum
Particulate* (gr/SCF)	.974	.669	.464
Particulate (gr/SCF)	.349	.263	.205
Particulate size (μm)	---	1.4	---
Chloride mg/m^3 (ppm)	255 (176)	197 (136)	111 (77)
O_2 (percent)	15.7	13.8	11.8
CO_2 percent (Orsat)	6.6	5.3	4.0
CO_2 percent (NDIR)	11.6	5.1	0.4
CO mg/m^3 (ppm)	ND	ND	ND
H_2O (percent)	9.3	7.1	4.5

* Corrected to 12 percent CO_2.

ND None detected.

averaged 8131 SCFM and 227°C. On the average, the moisture in the flue gas was 7.1 percent of the total gas volume. Corrected to 12 percent CO_2, the particulate concentration (gr/SCF) averaged .669 over nine tests with a maximum of .974 and a minimum of .464. Since this facility is subject to local regulation as a carbonaceous fuel burner, the applicable emission standards permit a Ringleman 1. The observed emission rate during the test averaged 17 lb/hr. The particulate size distribution analyses (see Figure 4-2) indicated that 95% by weight of the particles were smaller than 24 μm, and 50% by weight were smaller than 1.4 μm.



● Run 1 12/09/80
○ Run 2 12/09/80
△ Run 1 12/10/80
▲ Run 2 12/10/80

Figure 4-2. Particulate size distribution.

The metals concentration of stack particulates was determined by ICP emission techniques on a composite Method 5 filter sample. This sample was taken from one Method 5 filter of each day tested. The contribution of the filter to the instrument signal was subtracted from these data. Table 4-27 shows the results of this analysis. Results have been expressed in terms of the average concentration in the gas stream ($\mu g/m^3$) and in terms of the mass throughput of refuse (g/Mg of refuse). Major components of the particulate associated metals are aluminum, calcium, copper, iron, sodium, lead, phosphorus, and zinc.

The chloride concentration of the stack gases was determined titrametrically from the first impinger of the Method 5 train runs. The mean chloride concentration was 197 mg/m^3, with a maximum of 255 mg/m^3 and a minimum of 111 mg/m^3. Results of the chloride analysis are included in the Appendix.

EMISSIONS MEASURED AT BOILER OUTLET

Table 4-28 summarizes the results of the flue gas measurements taken at the boiler outlet. No data on NO_x emissions could be obtained because of a malfunction in the continuous monitoring instrument. The average concentrations of species measured were as follows: 66 mg/m^3 SO_x, 12.8 percent O_2, 7.1 percent CO_2, and 36 mg/m^3 CO. The maximum and minimum readings observed are also shown.

AMBIENT TEST CONDITIONS

Ambient test conditions were recorded during the test period to provide supporting data for emission calculations and general information relevant to the interpretation of test results. Table 4-29 shows test period average ambient temperature, relative humidity, barometric pressure, and precipitation.

TABLE 4-27. INDUCTIVELY COUPLED PLASMA ELEMENTAL ANALYSIS OF STACK EMISSION FILTERS

Element	Emission rate	
	Concentration in gas ($\mu g/m^3$)	Emission factor (g/Mg of refuse)
Al	3715	54.98
Ba	---	---
Be	---	---
B	---	---
Ca	662	9.80
Cd	443	6.56
Co	6.33	.09
Cr	77.7	1.15
Cu	1042	15.42
Fe	1451	21.47
Mg	173	2.56
Mn	321	4.75
Mo	36.3	.54
Na	18140	268.47
Ni	30.5	.45
Pb	4187	61.97
P	1762	26.08
Sb	228	3.37
Si	2.30	.03
Sn	175	2.59
Sr	20.7	.31
Ti	232	3.43
V	55.3	.82
Zn	10959	162.19
Ag	6.91	.10

TABLE 4-28. EMISSIONS CONCENTRATIONS AT BOILER OUTLET

Parameter	Emission concentrations Maximum	Average	Minimum
SO_x mg/m^3 (ppm)	105 (40)	66.2 (25.3)	26.2 (10)
NO_x mg/m^3 (ppm)	*	*	*
O_2 percent	16.3	12.8	5.3
CO_2 percent	13.0	7.7	3.5
CO mg/m^3 (ppm)	81 (71)	36 (31)	ND

* No data available.

ND None detected.

TABLE 4-29. AMBIENT TEST CONDITIONS

Test condition	Recorded data test period average
Ambient temperature (°C)	80
Relative humidity (%)	85
Barometric pressure (in. Hg)	30.2
Precipitation (in.)	None

SECTION 5

OBSERVATIONS AND DISCUSSION

During the test period, SYSTECH staff observed the operations of the facility for any effects which equipment layout and mode of operation have on the system performance. The plant layout is very good. The entire facility is located within a building, and adequate access to all equipment permits maintenance to be carried out routinely and easily. The tipping floor is sufficiently large for the current throughput rate which, however, is only 50 percent of designed capacity. If the plant is operated at full capacity, room for floor storage prior to sorting could preempt floor space necessary for the sorting procedure. The scale system for weighing the incoming refuse lacks a good communication system between the truck on the scale and the plant control room.

Even though the large metal and bulky items were a small percentage of the total waste, they necessitated hand removal before pushing the waste into the pit. It is assumed that these large items could jam the loading ram, thus reason for their removal. The separation of large metals and bulky items consumes time and auxiliary fuel. At full capacity, two laborers may be required to process and maintain floor space.

The results of the sorting and analyzing of the solid waste were similar to those expected. The November composition was similar to December sorting results. The heating value was 5134 Btu/lb. The precision in the measurements of the combustible components, cardboard and paper, impacts the mass and energy balances presented in this report. The other components do not impact these results to a significant degree. The refuse samples taken for composition analyses were of sufficient size to predict the amount of cardboard and paper with good precision.

Water is used to cool the feed hopper throat and to quench the residue in the ash pit. Although access was not available to measure the water flow, the discharge from the ash quench tank appeared to be substantial. This discharge may have a measurable adverse impact on the sewer and water fees paid by the incinerator plant.

The incineration function of the facility was very effective. Some 98 percent of the combustibles (on a dry weight basis) were completely burned. A value of 97 percent is considered superior in a system with a grate. However, the throughput rate was only 50 percent of the stated design capacity of the system. The amount of fuel oil burned in the secondary chamber accounted for 40 percent of the total heat input. This could be a major reason for the low solid waste input level. The fuel oil could be consuming

combustion volume in the secondary combustion chamber that was designed for the burning of gases produced from the pyrolyzing of refuse in the primary combustion chamber.

Primary combustion chamber temperature varied from 800 F to 1400 F, too wide a range for well controlled energy recovery. The secondary combustion chamber exit temperature was between 1500 F and 1600 F. More efficient heat recovery would occur in the 1800 F range.

The radiative and convective (R/C) heat losses calculated were 18 percent of the total energy lost. This is to be expected for a system with a large surface area such as this one but is nearly three times that calculated for similar capacity starved-air systems. The overall thermal efficiency of the system was only 49%. This is somewhat lower than the 50 to 60 percent measured on starved-air systems. This lower efficiency was due to higher radiative and convective losses, and the high excess air levels.

As discussed in the following paragraphs, the results of the sampling in the stack of the flue gases showed that (1) the particulate loading was 17 lb/hr, (2) the size distribution of the particulate was closer to that emitted from a waterwall unit than that of a starved-air incinerator, (3) the carbon content of the particulate was low, and (4) the SO_2 content was low.

The high level of particulate loading was due to the entrainment of particulates in the primary combustion chamber by the high levels of overfire and underfire air. The low carbon content indicates that the retention time and airflows are adequate to reduce the combustibles in the particulates.

The average particle size was not as small as that from a starved-air system. However, it was small enough to make the multicyclone system ineffective. Only 2% of the total particulate emitted from the primary combustion chamber was removed by the cyclone, while in comparison 3% was removed by the boiler.

The SO_2 content of the flue gases was typical of municipal incinerator systems. The low sulfur in the waste and the fact that some sulfur is trapped in the bottom ash results in low SO_2 emission rates. The chlorine concentration also was typical of municipal incinerator systems.

SECTION 6

RECOMMENDATIONS

Based on observations made during the test and analysis of the test results, the following recommendations are made:

1. An intercom or horn alarm would allow for communication between the scale and control rooms.

2. Provide a uniform load on the boiler, if possible, by automatically dumping steam or by increasing the use of steam.

3. A separate boiler for waste oil should be installed which would have better than the 63 percent efficiency as was measured in the November test on the incinerator while burning oil alone.

4. This new waste oil boiler could be used to meet the fluctuating steam demand.

5. A different burner should be installed in the secondary chamber to allow greater turndown and thus burn less oil in the secondary chamber.

6. Individual airflows should be measured and a combustion test conducted to determine why a 2-TPH capacity cannot be reached and why the excess air level is higher than required.

7. Routine maintenance and calibration of instrumentation should be provided. Periodically, the thermocouples, pressure gauges, and the meters and recorders should be calibrated or replaced.

8. A soot blower installed on the boiler would reduce maintenance and improve overall efficiency.

9. Burnout should be sacrificed to increase throughput during periods of high steam demand. A combustible content of 10 percent instead of 5 percent in the bottom ash should still be achievable and yet should not be objectionable.

10. An emissions control device such as a baghouse could be used to reduce emissions if desired.

11. The multicyclones do not appear to be effective. Their removal from the system would simplify operation and reduce power consumption by the ID fan.

12. A dump stack cap that will close more completely should be designed and installed.

13. Evaluate the possibility of reducing the cooling water flow or redirecting it for other uses.

APPENDIX

Included in the Appendix are a number of data and calculation sheets supporting the various measurements and calculations discussed in the text. These pages are organized into six separate sections describing the following elements: (1) refuse characterization, (2) residue characterization, (3) process data, (4) mass and energy balances and performance calculations, (5) quality assurance data for metals and EP toxicity analyses, and (6) November mass and energy balance calculations.

Refuse Characterization

REFUSE CHARACTERIZATION DATA SHEET (lb)

Date 11/17/80 Monday BASE X MUNICIPAL ____

Category	Tare Wt	Sample Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Sample - Tare Total	Percent as-received
Cardboard	8	20	20	37	28	33	25	35	33	23 34 40	240	18.5
Other paper	5	30	32	41	41	20	34				168	13.0
Food waste	5	63	24	37							109	8.4
Yard Waste	5	10									5	0.4
Wood	8	68	26	35							105	8.1
Ferrous	5	26	13								29	2.2
Aluminum	8	34	23	10							43	3.3
Other metals	4	10	15								21	1.6
Glass	8	26									18	1.4
Plastics	8	31	28	28	27	33					107	8.3
Textiles	4	26	47	36	18	15	8				126	9.7
Inerts	4	69									65	5.0
Fines	5	102	50	28	98						258	19.9
										Total	1294	99.8

REFUSE CHARACTERIZATION DATA SHEET

Date 11/18/80 BASE X MUNICIPAL ____

Category	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Tare Wt	Total	Percent as-received
Cardboard	31	38	31	24	23	20	21			8	132	18.21
Other paper	45	36	35	32	41	27	8			5	189	26.07
Food waste	18									5	13	1.79
Yard Waste	9	6								5	5	0.69
Wood	48	12	12							8	48	6.62
Ferrous	26	17	16							5	44	6.07
Aluminum	14									8	6	0.83
Other metals										4	-	-
Glass	43									8	35	4.83
Plastics	33	36	20							8	65	8.97
Textiles	25	18	8							4	39	5.38
Inerts	15									4	11	1.52
Fines	78	70								5	138	19.03
										Total	725	100.00

REFUSE CHARACTERIZATION DATA SHEET

Date 11/19/80 BASE X MUNICIPAL ______

Category	Tare Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Total	Percent as-received
Cardboard	0	37.0	35.5	25.0	17.0						82.5	10.36
Other paper	5	29.5	26	35.5	26.0	32.0	29.0	40	23.0	20.5	216.5	27.20
Food waste	5	12.0	10.0								12.0	1.51
Yard Waste	5	13	47	31.5	18.0	13					97.5	12.25
Wood	8	23									15.0	1.88
Ferrous	5	29.0	20.5	10.5							45.0	5.65
Aluminum	8	12.0	10.0								6.0	0.75
Other metals	2.0	3.5									1.5	0.19
Glass	8	42.0	16								42.0	5.28
Plastics	8	24.5	24.5	23.5	16.5						57.0	7.16
Textiles	4	13.5	(hoses) 35	17							53.5	6.72
Inerts	2.0	11.5	3.5								11.0	1.38
Fines	5	57.5	54	60							156.5	19.66
										Total	796	100.00

REFUSE CHARACTERIZATION DATA SHEET

Date 11/20/80 BASE X MUNICIPAL ____

Category	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Total	Percent as-received
Cardboard	15.0	35.0	16.5	30.0	25.0	23.0					144.5	15.16
Other paper	57.0	25.5	48.0	43.0	40.0	25.0	47.0	22.0			307.5	32.27
Food waste	29.0	20.0									49.0	5.14
Yard Waste	18.0	10.0	9.5								37.5	3.93
Wood	32.0										32.0	3.36
Ferrous	32.0	19.0									51.0	5.35
Aluminum	11.0	8.5									19.5	2.05
Other metals	3.5										3.5	.36
Glass	30.0	13.0									43.0	4.51
Plastics	30.0	25.0	20.0	10.0							85.0	8.92
Textiles	16.0	10.5	11.0								37.5	3.93
Inerts	13.0										13.0	1.36
Fines	29.5	12.5	50.0	38.0							130.0	13.64
										Total	953.0	

REFUSE CHARACTERIZATION DATA SHEET

Date 12/08/80 BASE #1 MUNICIPAL ______

Category	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Total	Percent as-received
Cardboard	25.00	22.75	26.25	27.25	27.25	16.25	20.50	4.50			169.75	14.79
Other paper	23.25	19.75	9.50	29.5	19.75	29.5	31.25	11.75	19.50	127.75*	321.25	27.98
Food waste	23.25										23.25	2.03
Yard Waste	13.50	15.25	10.50	11.75	10.25						61.25	5.34
Wood	38.00										38.00	3.31
Ferrous	22.00	26.75	0.75								49.50	4.31
Aluminum	9.50										9.50	.82
Other metals	3.50										3.50	.30
Glass	49.75	3.25									53.00	4.62
Plastics	20.50	70.50	5.50	12.75	17.5	33.25					100.0	8.71
Textiles	7.73	13.00	11.50	0.75	82.50						115.5	10.06
Inerts	2.75										2.75	.24
Fines	40.75	71.75	88.25								200.75	17.49
										Total	1148.00	100.00

* Sum of 4 separate weights

REFUSE CHARACTERIZATION DATA SHEET

Date 12/08/80 BASE #2 MUNICIPAL ____

Category	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Total	Percent as-received
Cardboard	18.75	33.50	12.50	13.50	24.50	28.50	32.50	24.50	21.75	233.75*	443.75	18.36
Other paper	35.75	11.75	7.00	12.25	47.50	31.25	33.25	45.5	32.00	360.25†	616.50	25.51
Food waste	87.00	38.75	20.25								146.00	6.04
Yard Waste	26.00	19.50	7.50	94.00							147.00	6.08
Wood	34.50	47.50	2.50	2.00							86.50	3.58
Ferrous	11.25	37.50	39.50	21.25	3.50						113.00	4.67
Aluminum	14.00	11.25	2.75								28.00	1.16
Other metals	23.75	5.00									29.25	1.21
Glass	85.00	18.75									103.75	4.29
Plastics	22.25	4.50	15.00	27.00	23.00	20.00	33.50	25.50	13.75	113.25††	297.75	12.32
Textiles	18.25	44.00	30.50	20.25	25.75	14.00	3.00				155.75	6.44
Inerts	9.75	3.25									13.00	0.54
Fines	123.50	54.00	59.50								237.00	9.80
										Total	2417.25	100.00

* Sum of 9 separate weights
† Sum of 10 separate weights
†† Sum of 4 separate weights

REFUSE CHARACTERIZATION DATA SHEET

Date 12/09/80 BASE #4 MUNICIPAL ______

Category	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Total	Percent as-received
Cardboard											130.25	12.19
Other paper											368.50	34.50
Food waste											102.50	9.59
Yard Waste											54.75	5.12
Wood											33.50	3.14
Ferrous											71.00	6.64
Aluminum											10.25	0.96
Other metals											18.75	1.75
Glass											24.75	2.32
Plastics											97.50	9.12
Textiles											59.50	5.57
Inerts											47.25	4.42
Fines											50.00	4.68
										Total	1068.50	100.00

REFUSE CHARACTERIZATION DATA SHEET

Date 12/09/80 BASE #3 MUNICIPAL ______

Category	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Wt	Total	Percent as-received
Cardboard											277.50	15.45
Other paper											540.75	30.11
Food waste											103.00	5.73
Yard Waste											129.75	7.22
Wood											41.50	2.31
Ferrous											98.50	5.48
Aluminum											20.00	1.11
Other metals											42.50	2.37
Glass											115.00	6.40
Plastics											202.75	11.29
Textiles											77.25	4.30
Inerts											9.25	0.51
Fines											138.75	7.72
										Total	1796.50	100.00

REFUSE MOISTURE DATA SHEET

Date 11/17/80 Analyst P.F.C. Base X Municipal ____

Category	(1) Tray tare weight (g)	(2) Gross sample weight (g)	(3) Dry gross sample weight (g)	(4) Moisture content (%)	
Cardboard	141.0	385.4	348.6	15.06	
Other paper	504.2	954.8	820.0	29.92	
Food waste	154.5	554.4	207.5	86.75	
Yard Waste		None			
Wood	154.5	779.8	647.3	21.19	
Ferrous	149.2	427.1	410.3	6.05	
Aluminum	181.5	472.4	443.2	10.04	
Other metals		None			
Glass	486.2	1561.4	1522.1	3.66	
Plastics	488.3	704.7	680.0	11.41	
Textiles	190.0	715.8	539.9	33.45	
Inerts		None			
Fines	154.5	1192.2	860.0	32.01	

$$\text{Moisture percent} = 100 \times \frac{\text{Gross sample weight} - \text{Dry gross weight}}{\text{Gross sample weight} - \text{Tare weight}} \; (4) = \frac{(2) - (3)}{(2) - (1)} \times 100$$

eet 1 of 2

REFUSE MOISTURE DATA SHEET

Date 11/17/80 Analyst P.F.C. Base X Municipal ______

Category	(1) Tray tare weight (g)	(2) Gross sample weight (g)	(3) Dry gross sample weight (g)	(4) Moisture content (%)	
Cardboard	157.7	302.9	279.1	16.39	
Other paper	487.7	921.4	787.2	30.94	
Food waste		-			
Yard Waste		-			
Wood	180.5	648.9	493.6	33.16	
Ferrous		-			
Aluminum		-			
Other metals		-			
Glass		-			
Plastics		-			
Textiles		-			
Inerts		-			
Fines	191.2	1220.0	872.3	33.80	

$$\text{Moisture percent} = 100 \times \frac{\text{Gross sample weight} - \text{Dry gross weight}}{\text{Gross sample weight} - \text{Tare weight}} \quad (4) = \frac{(2) - (3)}{(2) - (1)} \times 100$$

Sheet 2 of 2

REFUSE MOISTURE DATA SHEET

Date 11/18/80 Analyst P.F.C. Base X Municipal ____

Category	1 Tray tare weight (g)	2 Gross sample weight (g)	3 Dry gross sample weight (g)	4 Moisture content (%)	All samples dated 11/19
Cardboard	488.3	726.1	652.0	31.16	
Other paper	181.9	518.2	395.3	36.54	
Food waste	181.8	498.0	274.9	70.56	
Yard Waste	157.8	224.4	198.2	39.34	
Wood	190.0	918.1	830.0	12.1	
Ferrous	478.9	1040.0	1000.6	7.02	
Aluminum	167.7	335.5	310.0	15.2	
Other metals	None	None	None	-	-
Glass	154.6	591.3	588.7	.53	
Plastics	485.8	551.3	546.8	6.87	
Textiles	N/A	1660.0	Lost	Sample	Burned
Inerts	149.1	642.3	598.9	8.8	
Fines	154.4	1278.2	782.0	44.15	

$$\text{Moisture percent} = 100 \times \frac{\text{Gross sample weight} - \text{Dry gross weight}}{\text{Gross sample weight} - \text{Tare weight}} \quad 4 = \frac{2 - 3}{2 - 1} \times 100$$

REFUSE MOISTURE DATA SHEET

Date 11/18/80 Analyst P.F.C. Base X Municipal ____

Category	(1) Tray tare weight (g)	(2) Gross sample weight (g)	(3) Dry gross sample weight (g)	(4) Moisture content (%)	All samples dated 11/19
Cardboard	486.1	774.8	701.3	25.46	
Other paper	189.0	486.5	332.4	51.8	
Food waste					
Yard Waste					
Wood	153.4	574.3	457.3	27.8	
Ferrous					
Aluminum					
Other metals					
Glass					
Plastics					
Textiles					
Inerts					
Fines	156.3	1024.3	695.2	37.91	

$$\text{Moisture percent} = 100 \times \frac{\text{Gross sample weight} - \text{Dry gross weight}}{\text{Gross sample weight} - \text{Tare weight}} \quad (4) = \frac{(2) - (3)}{(2) - (1)} \times 100$$

REFUSE MOISTURE DATA SHEET

Date 11/19/80 Analyst P.F.C. Base X Municipal ____

Category	(1) Tray tare weight (g)	(2) Gross sample weight (g)	(3) Dry gross sample weight (g)	(4) Moisture content (%)	
Cardboard	156.0	260.3	247.1	12.65	
Other paper	154.3	374.2	307.2	30.46	
Food waste	496.1	1105.8	751.6	58.09	
Yard Waste	155.0	499.4	384.9	33.24	
Wood	188.9	1330.0	1176.7	33.24	
Ferrous	488.9	1252.3	1234.1	2.38	
Aluminum	153.9	351.2	310.9	20.42	
Other metals	167.6	301.0	300.0	0.74	
Glass	478.1	1059.4	1058.7	0.12	
Plastics	479.7	653.4	647.0	3.68	
Textiles	485.2	810.0	783.9	8.03	
Inerts	156.8	560.9	433.5	31.52	
Fines	182.9	657.8	489.9	35.35	

$$\text{Moisture percent} = 100 \times \frac{\text{Gross sample weight} - \text{Dry gross weight}}{\text{Gross sample weight} - \text{Tare weight}} \quad (4) = \frac{(2) - (3)}{(2) - (1)} \times 100$$

REFUSE MOISTURE DATA SHEET

Date 11/19/80 Analyst P.F.C. Base X Municipal ____

Category	(1) Tray tare weight (g)	(2) Gross sample weight (g)	(3) Dry gross sample weight (g)	(4) Moisture content (%)	
Cardboard	181.4	497.1	374.2	38.92	
Other paper	189.9	324.7	309.2	11.49	
Food waste					
Yard Waste	148.7	337.6	283.3	28.74	
Wood					
Ferrous					
Aluminum					
Other metals					
Glass					
Plastics					
Textiles					
Inerts					
Fines					

$$\text{Moisture percent} = 100 \times \frac{\text{Gross sample weight} - \text{Dry gross weight}}{\text{Gross sample weight} - \text{Tare weight}} \quad (4) = \frac{(2) - (3)}{(2) - (1)} \times 100$$

REFUSE MOISTURE DATA SHEET

Date 11/20/80 Analyst P.F.C. Base X Municipal ____

Category	1 Tray tare weight (g)	2 Gross sample weight (g)	3 Dry gross sample weight (g)	4 Moisture content (%)	
Cardboard	152.4	401.5	361.2	16.2	
Other paper	155.8	239.1	230.0	10.9	
Food waste	213.4	559.1	349.6	60.6	
Yard Waste	478.6	509.6	499.6	32.3	
Wood	154.6	389.2	353.8	15.1	
Ferrous	496.7	1126.9	1010.0	18.5	
Aluminum	190.7	377.4	353.4	12.9	
Other metals	187.6	464.7	463.4	0.5	
Glass	148.9	625.1	619.5	1.2	
Plastics	156.6	320.0	310.7	5.7	
Textiles	181.3	544.2	540.1	1.1	
Inerts	181.1	255.4	253.9	2.0	
Fines	490.4	784.4	630.6	52.3	

$$\text{Moisture percent} = 100 \times \frac{\text{Gross sample weight} - \text{Dry gross weight}}{\text{Gross sample weight} - \text{Tare weight}} \quad 4 = \frac{2 - 3}{2 - 1} \times 100$$

REFUSE MOISTURE DATA SHEET

Date 11/20/80 Analyst P.F.C. Base X Municipal ____

Category	(1) Tray tare weight (g)	(2) Gross sample weight (g)	(3) Dry gross sample weight (g)	(4) Moisture content (%)	
Cardboard	154.3	434.0	377.6	20.2	
Other paper	484.6	567.1	543.2	28.9	
Food waste					
Yard Waste					
Wood					
Ferrous					
Aluminum					
Other metals					
Glass					
Plastics					
Textiles					
Inerts					
Fines	482.8	810.0	684.2	38.4	

$$\text{Moisture percent} = 100 \times \frac{\text{Gross sample weight} - \text{Dry gross weight}}{\text{Gross sample weight} - \text{Tare weight}} \quad 4 = \frac{2 - 3}{2 - 1} \times 100$$

DAILY WASTE CHARACTERIZATION RESULTS

Day ________ Date Nov. 17-20, 1980 Location ____________

Base waste ✓ or Municipal waste ________

Category	Composition (% wt) November						Moisture (%) November					
	M	T	W	Th		Numerical average	M	T	W	Th		Numerical average
Cardboard	18.5	18.2	10.4	15.2		15.6	15.7	28.3	25.8	18.2		22.0
Other paper	13.0	26.1	27.2	32.3		24.7	30.4	44.2	20.9	19.9		28.9
Food waste	8.4	1.8	1.5	5.1		4.2	86.8	70.6	58.1	60.6		69.0
Yard Waste	0.4	0.7	12.3	3.9		4.3	-	39.3	30.9	32.3		34.2
Wood	8.1	6.6	1.9	3.4		5.0	27.2	19.9	13.4	15.1		18.9
Ferrous	2.2	6.1	5.7	5.4		4.9	6.1	7.0	2.4	18.5		8.5
Aluminum	3.3	0.8	0.8	2.1		1.8	10.0	15.2	20.4	12.9		14.6
Other metals	1.6	-	0.2	0.4		0.6	-	-	0.7	0.5		0.6
Glass	1.4	4.8	5.3	4.5		4.0	3.7	0.5	0.1	1.2		1.4
Plastics	8.3	8.9	7.2	8.9		8.3	11.3	6.9	3.7	5.7		6.9
Textiles	9.7	5.4	6.7	3.9		6.4	33.5	X	8.0	1.1		14.2
Inerts	5.0	1.5	1.4	1.4		2.3	-	-	31.5	2.0		16.8
Fines	19.9	19.0	19.7	13.6		18.1	32.9	44.2	41.0	45.4		40.9

(-) denotes none found
(X) denotes lost data (destroyed sample)

DAILY WASTE CHARACTERIZATION RESULTS

Day ________ Date Dec. 8-9, 1980 Location ____________

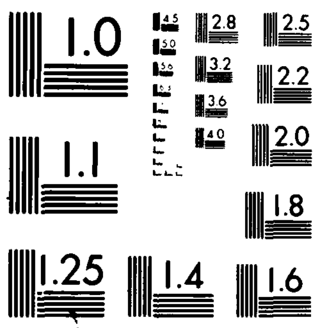
Base waste X or Municipal waste ________

Category	Composition - December (% wt)					Numerical average
	M		T			
Cardboard	14.8	18.4	15.4	12.2		15.2
Other paper	27.9	25.5	30.1	34.5		29.5
Food waste	2.0	6.0	5.7	9.6		5.8
Yard Waste	5.3	6.1	7.2	5.1		5.9
Wood	3.3	3.6	2.3	3.1		3.1
Ferrous	4.3	4.7	5.5	6.6		5.3
Aluminum	0.8	1.2	1.1	0.9		1.0
Other metals	0.3	1.2	2.4	1.8		1.4
Glass	4.	4.3	6.4	2.3		4.4
Plastics	8.7	12.3	11.3	9.1		10.4
Textiles	10.1	6.4	4.3	5.6		6.6
Inerts	0.2	0.5	1.0	4.4		1.5
Fines	17.5	9.8	7.7	4.7		9.9

AD-A099 559   SYSTECH CORP XENIA OH   F/G 13/2
TEST AND EVALUATION OF THE HEAT RECOVERY INCINERATOR SYSTEM AT --ETC(U)
MAY 81   N68305-80-C-0006
UNCLASSIFIED   CEL-CR-81.012   NL

2 of 2

END
DATE
FILMED
7-81
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

WEEKLY REFUSE HEATING VALUE CALCULATION SHEET

Base waste X or Municipal waste ______

Category	(1) Category weight (lb)	(2) Moisture (%)	(3) Dry weight (lb)	(4) HHV (Btu/lb)	(5) Heat input (Btu)
Cardboard	24,314	22.0	18,965	7,791	147.8×10^6
Other paper	47,188	28.9	33,551	7,429	249.3×10^6
Food waste	9,278	69.0	2,876	8,162	23.5×10^6
Yard waste	9,438	34.2	6,210	7,282	45.2×10^6
Wood	4,959	18.9	4,022	8,253	33.2×10^6
Plastics	16,636	6.9	15,488	13,630	211.1×10^6
Textiles	10,557	14.2	9,058	8,793	79.6×10^6
Fines	15,836	40.9	9,359	3,457	32.4×10^6
Ferrous	8,478	8.5	7,757	---	---
Aluminum	1,600	14.6	1,366	---	---
Other metals	2,239	0.6	2,226	---	---
Glass	7,038	1.4	6,939	---	---
Inerts	2,399	16.8	1,996	---	---
Totals	159,960	---	119,813	---	821.2×10^6

Category weight = Weight percent × Total week weight (as-received basis)

$$CV_4 = \frac{\text{Total heat input}}{\text{Total week weight}} \quad \text{or} \quad \frac{(5)\ \text{Total}}{(1)\ \text{Total}}$$

CV_4 = 5134 Base X Municipal ______

$$(3) = (1) \times \left(1 - \frac{(2)}{100}\right)$$

$$(5) = (3) \times (4)$$

ULTIMATE ANALYSIS CALCULATIONS

Base ___X___ Municipal ______

(Dry weight basis)

Category	Dry weight (lb)	Total (F)	C	X(F)	H	X(F)	O	X(F)	N	X(F)	Cl	X(F)	S	X(F)	I	X(F)
Cardboard	18,965	.16	46.0	7.36	6.3	1.01	44.3	7.09	.14	.02	.15	.02	.29	.05	2.8	.45
Other paper	33,551	.27	42.1	12.37	5.8	1.57	38.8	10.48	.40	.11	.79	.21	.25	.07	11.8	3.19
Food waste	2,876	.02	44.8	.89	6.4	.13	32.1	.64	2.8	.06	.95	.02	.15	--	12.7	.25
Yard waste	6,210	.05	42.3	2.12	5.3	.27	31.9	1.59	1.6	.08	.24	.01	.27	.01	18.3	.92
Wood	4,022	.04	49.0	1.96	6.0	.24	41.1	1.64	.28	.01	.11	--	.05	--	3.3	.13
Plastics	15,488	.13	66.4	7.97	9.2	1.10	9.5	1.14	1.0	.12	3.5	.42	.34	.04	10.1	1.21
Textiles	9,058	.08	49.6	3.97	6.7	.54	36.1	2.89	4.1	.33	.36	.03	.37	.03	2.1	.17
Fines	9,359	.08	20.0	1.60	2.5	.20	16.2	1.30	0.66	.05	.48	.04	.20	.02	59.9	4.79
Ferrous	7,757	.06	4.5	.27	0.6	.04	4.2	.25	.05	--	.07	--	.01	--	90.5	5.43
Aluminum	1,366	.01	4.5	.05	0.6	.01	4.2	.04	.05	--	.07	--	.01	--	90.5	.91
Other metals	2,226	.02	4.5	.09	0.6	.01	4.2	.08	.05	--	.07	--	.01	--	90.5	1.81
Glass	6,939	.06	0.5	.03	.07	--	0.36	.02	.03	.03	.01	--	---	--	99.0	5.94
Inerts	1,996	.02	0.5	.01	.07	--	0.36	.01	.03	--	.01	--	---	--	99.0	1.98
Totals	119,813	1.00		38.69		5.12		27.17		.81		.75		.22		27.18

Lower heating value calculation (as-received basis)

$$LHV = HHV - 1060 \left(\frac{9\ H\ (100 - \%\ H_2O)}{10,000} + \frac{\%\ H_2O}{100} \right)$$

$$LHV = \underline{5134} - 1060 \left(\frac{9(\underline{5.12})(100 - \underline{25.1})}{10,000} + \frac{25.1}{100} \right)$$

$$LHV = 4502$$

Where:

H = Percent hydrogen content on dry weight basis

% H_2O = Moisture content on as-received basis

HHV = Higher heating value on as-received basis

Residue Characterization

RESIDUE MOISTURE DATA

Date ________ Location ____________ Analyst __________

Date	Tray tare (g)	Wet sample **net** (g)	Dry sample **net** (g)	Moisture content (%)
11/17/80		3350	2281	31.91
11/17/80		2448	1665	31.99

Average 31.95 %

$$\text{Moisture content} = 100 \times \frac{\text{Wet sample net} - \text{Dry sample}}{\text{Wet sample net}}$$

RESIDUE MOISTURE DATA

Date Dec 8,9,10, 1980 Location Mayport Analyst M.R.

Date	Tray tare (kg)	Wet sample gross (kg)	Dry sample gross (kg)	Moisture content (%)
12/08/80	.470	1.820	1.26	41.5
"	.340	2.400	1.86	26.2
"	.140	1.91	1.39	29.4
"	.140	2.77	2.03	28.1
12/09/80	.470	2.60	1.94	31.0
"	.340	2.24	1.65	31.0
"	.140	2.03	1.40	33.3
"	.140	2.44	1.64	34.8
"	.150	3.37	2.20	36.3
12/10/80	.47	2.38	1.74	33.5
"	.34	2.31	1.70	31.0
"	.14	2.40	1.73	29.7
"	.14	2.18	1.50	33.3
"	.14	2.24	1.46	37.1
"	.14	2.30	1.58	33.3

Average 32.6 %

$$\text{Moisture content} = 100 \times \frac{\text{Wet sample gross} - \text{Dry sample gross}}{\text{Wet sample gross} - \text{Tray tare}}$$

COMBUSTIBLES ANALYSIS DATA SHEET

Date Dec 8,9,10, 1980 Location Mayport Analyst M. R.

Residue X Fly ash ____

Sample date	Dry analysis sample (g)*/Dry ash sample (g)	Dry analysis sample net wt. (g)	Ashed analysis sample net wt. (g)	Analysis sample Combustibles content (%)	Dry residue Combustibles content (%)
12/08/80	0.34	40.4042	36.4652	9.8	3.3
12/09/80	0.55	35.8721	31.6975	11.6	6.4
12/10/80	0.50	35.3500	32.5386	8.0	4.0

$$\text{Combustibles content of analysis sample} = \frac{\text{Dry sample gross wt} - \text{Ashed sample gross wt}}{\text{Dry sample gross wt} - \text{Tray tare}}$$

$$\text{Combustibles content of dry residue} = \text{combustibles content of analysis samples} \times \frac{\text{dry wt of analysis sample}}{\text{dry wt of ash sample}}$$

* Analysis sample represents dry ash sample from which obviously noncombustible materials have been removed.

DAILY DRY ASH OUTPUT

Weekly average residue moisture 31.95 percent (wet weight basis)

Weekly average residue HHV 1417 Btu/lb (dry weight basis)

Day	Date	Wet ash output (lb)	Dry ash output (lb)	Ash heat lost (Btu)
M	12/08/80	5,660	3,852	5.46×10^6
T	12/09/80	15,540	10,575	14.99×10^6
W	12/10/80	17,180	11,691	16.57×10^6
TH	12/11/80	18,140	12,344	17.49×10^6
F				
Total		56,520	38,462	54.51×10^6

$$\text{Dry ash output} = \text{wet ash output} \times \left(1 - \frac{\text{weekly average moisture}}{100}\right)$$

Ash heat lost = dry ash output × average weekly HHV (dry weight basis)

Process Data

Day Thursday-Friday
Date 4-5 Dec   Analyst ____________

BASE WASTE
DAILY REJECTS

Daily total gross waste delivered	82,337	
Weight of rejects	- 5,286	
Net weight refuse supplied to pit	= 77,051	$[M_{12n}]$

MUNICIPAL WASTE
DAILY REJECTS

Daily total gross waste delivered	______	
Weight of rejects	- ______	
Net weight refuse supplied to pit	= ______	$[M_{12n}]$

Day Monday
Date 8 Dec Analyst ____________

BASE WASTE
DAILY REJECTS

Daily total gross waste delivered	51,680	
Weight of rejects	- 3,318	
Net weight refuse supplied to pit	= 48,362	[M_{12n}]

MUNICIPAL WASTE
DAILY REJECTS

Daily total gross waste delivered	____	
Weight of rejects	- ____	
Net weight refuse supplied to pit	= ____	[M_{12n}]

Day Tuesday
Date 9 Dec Analyst ______________

BASE WASTE
DAILY REJECTS

Daily total gross waste delivered		21,540	
Weight of rejects	-	1,383	
Net weight refuse supplied to pit	=	20,157	[M_{12n}]

MUNICIPAL WASTE
DAILY REJECTS

Daily total gross waste delivered			
Weight of rejects	-		
Net weight refuse supplied to pit	=		[M_{12n}]

Day Wednesday
Date 10 Dec   Analyst ____________

BASE WASTE
DAILY REJECTS

Daily total gross waste delivered		15,420	
Weight of rejects	-	990	
Net weight refuse supplied to pit	=	14,430	$[M_{12n}]$

MUNICIPAL WASTE
DAILY REJECTS

Daily total gross waste delivered		____	
Weight of rejects	-	____	
Net weight refuse supplied to pit	=	____	$[M_{12n}]$

NS Mayport HRI

Analyst ________________

SOLID WASTE FEED RATE DATA
(charged loads only)

December 8-11, 1980

Weight of load cell (ton)	Time	Weight of load cell (ton)	Time
.35	11:50 p.m.	.50	10:55 a.m.
.17	11:55 a.m.	.59	11:14 "
.47	12:20 "	.43	11:35 "
.37	12:35 "	.38	12:08 p.m.
.33	12:45 "	.26	12:35 "
.28	1:[illegible] "	.35	12:55 "
.30	1:15 "	.37	1:20 "
.47	1:45 "	.21	2:15 "
.38	2:05 "	.37	2:30 "
.42	2:35 "	.19	2:58 "
.25	2:55 "	.24	3:05 "
.35	3:16 "	.37	3:30 "
.40	4:07 "	.44	3:46 "
.41	4:11 "	.51	4:10 "
.53	4:50 "	.61	4:20 "
.32	4:55 "	.61	4:55 "
.40	5:50 "	.51	5:12 "
.41	5:55 "	.50	5:27 "
.46	6:55 "	.49	6:07 "
.36	7:10 "	.54	6:23 "
.52	7:15 "	.49	7:15 "
.30	7:52 "	.53	7:45 "
.54	8:00 "	.61	8:05 "
.62	8:34 "	.53	8:40 "
.52	9:10 "	.61	9:00 "
.40	9:25 "	.53	9:17 "
.29	9:50 "	.55	9:50 "
.33	10:05 "	.58	10:16 "
.45	10:50 "	.54	10:37 "

NS Mayport HRI Analyst ________________

SOLID WASTE FEED RATE DATA
(charged loads only)

December 8-11, 1980

Weight of load cell (ton)	Time	Weight of load cell (ton)	Time
.54	11:15 p.m.	.46	9:50 a.m.
.30	11:45 "	.42	10:06 "
.21	12:20 a.m.	.56	10:48 "
.38	12:25 "	.46	11:37 "
.37	12:55 "	.49	11:45 "
.50	1:20 "	.32	11:55 "
.39	1:45 "	.70	12:20 p.m.
.32	1:55 "	.31	1:12 "
.34	2:20 "	.31	1:20 "
.41	2:25 "	.38	1:30 "
.25	2:55 "	.40	1:50 "
.43	3:35 "	.53	2:00 "
.42	3:40 "	.34	2:40 "
.62	4:40 "	.26	3:00 "
.44	4:45 "	.10	3:20 "
.59	5:35 "	.48	3:50 "
.44	5:40 "	.40	4:20 "
.49	6:35 "	.39	4:40 "
.39	6:40 "	.33	5:05 "
.38	7:00 "	.56	5:40 "
.43	7:30 "	.38	6:10 "
.36	8:05 "	.31	6:40 "
.51	8:15 "	.38	6:50 "
.17	8:20 "	.34	7:20 "
.34	8:53 "	.52	7:48 "
.35	9:00 "	.38	8:11 "
.37	9:22 "	.54	8:29 "
.22	9:30 "	.36	9:00 "
.40	9:45 "	.41	9:35 "

NS Mayport HRI

Analyst ______________

SOLID WASTE FEED RATE DATA
(charged loads only)

December 8-11, 1980

Weight of load cell (ton)	Time	Weight of load cell (ton)	Time
.33	9:59 p.m.	.34	8:00 a.m.
.44	10:30 "	.24	8:10 "
.44	10:57 "	.66	8:30 "
.44	11:12 "	.88	8:55 "
.39	12:30 a.m.	.29	9:40 "
.38	12:35 "	.45	9:58 "
.28	1:15 "	.30	10:10 "
.45	1:45 "	.43	10:25 "
.35	2:10 "	.75	11:05 "
.29	2:40 "	.31	11:40 "
.39	2:45 "	.44	12:05 p.m.
.32	3:15 "	.34	12:20 "
.27	3:30 "	.34	12:50 "
.36	3:35 "	.13	12:55 "
.25	4:25 "	.31	2:00 "
.27	4:30 "	.27	2:15 "
.30	4:45 "	.33	2:30 "
.33	4:50 "	.62	3:02 "
.37	5:25 "	.42	3:15 "
.27	5:30 "	.35	3:50 "
.29	5:50 "	.35	4:10 "
.26	5:55 "	.36	4:22 "
.30	6:12 "	.45	4:45 "
.40	6:15 "	.38	5:07 "
.21	6:55 "	.39	5:40 "
.50	7:05 "	.41	6:15 "
.21	7:30 "	.39	6:40 "
.47	7:40 "	.54	6:58 "
.27	7:50 "	.42	7:23 "

NS Mayport HRI

Analyst ____________

SOLID WASTE FEED RATE DATA
(charged loads only)

December 8-11, 1980

Weight of load cell (ton)	Time	Weight of load cell (ton)	Time
.28	7:55 p.m.	.08	4.47 a.m.
.37	8:05 "		
.44	8:32 "		
.32	9:00 "		
.33	9:15 "		
.40	9:45 "		
.40	10:05 "		
.39	10:33 "		
.45	11:00 "		
.56	11:15 "		
.31	11:55 "		
.31	12:10 a.m.		
.41	12:45 "		
.41	1:05 "		
.51	1:15 "		
.50	1:30 "		
.27	2:05 "		
.41	2:20 "		
.45	2:40 "		
.47	3:25 "		
.24	3:30 "		
.15	3:35 "		
.40	3:51 "		
.16	4:03 "		
.16	4:23 "		
.46	4:27 "		
.32	4:39 "		
.09	4:43 "		
.11	4:45 "		

HOURLY PROCESS DATA

Date 12/08/80

Time	0000	0100	0200	0300	0400	0500	0600	0700
Gas pressure boiler entrance	- .30	- .5	- .5	- .35	- .5	- .5	- .5	- .5
Gas pressure leaving boiler	-1.0	-2.0	-2.0	-1.5	-1.9	-2.0	-2.0	-1.[illegible]
Pres. exit dust collector	2.0	4.0	4.0	3.0	-4.0	-4.0	-4.0	-4.0
Overfire air pressure	32	32	32	32	32	32	32	32
Hearth air pressure	32	32	32	32	32	32	32	32
Grate air pressure	0	0	0	0	0	0.2	0.1	0.1
Charge counts	0	28	48	68	95	119	144	173
ID fan current (amp)	55	57	57	58	58	57	57	58
Steam integrator	X	X	X	X	X	X	X	X
Load cell weight (tons)	0	1.69	2.76	3.81	4.10	5.77	6.58	7.04
Primary temperature (°F)	150	670	1,000	650	1,100	1,170	980	750
Secondary temperature (°F)	1100	1250	1400	1300	1500	1600	1510	1400
Fuel oil 1 (gal) Primary	220	220	220	220	220	220	220	220
Waste oil 1 (gal) Primary	15,615	15,615	15,615	15,615	15,615	15,615	15,615	15,615
Fuel oil 2 (gal) Secondary	326	326	326	326	326	326	326	326
Waste oil 2 (gal) Secondary	202,956	203,025	203,090	303,161	203,238	203,304	203,370	203,445
Makeup water No. 1 (gal) x 100	16,596	16,605	16,617	16,629	16,641	16,654	16,667	16,680
Makeup water No. 2 (gal) x 100	17,256	17,256	17,256	17,256	17,256	17,256	17,256	17,256
Feed water (gal) x 100	48,122	48,132	48,146	48,159	48,173	48,187	48,201	48,215
Continuous blowdown (gal) x 10	22,930	22,941	22,950	22,960	22,970	22,980	22,990	23,001
Continuous blowdown (gal)	X	X	X	X	X	X	X	X
Steam pressure (psig)	150	150	105	95	128	160	150	138
Steam calorimeter, temp. (°F)	-	-	-	-	-	282	-	-
Feed water temperature (°F)		?	?	180	180+	185-	180	180
Makeup water temperature (°F)		75	75	75	75	75	75	75
Blowdown temperature (°F)		100	120	110	120	120	130	130
Ambient temperature (°F)		70	70	70	70	70	70	70
Boiler outlet temperature (°F)		440	440	420	450	475	465	460
Flue gas O_2 (percent)		19	19	19	19.75	19.5	19.75	19.75
CO_2 (percent)		2.4	1.8	2.05	1.7	1.6	1.4	1.8
CO (ppm)		10	10	10	10	10	10	10

HOURLY PROCESS DATA

Date 12/8/80

Time	0800	0100	1000	1100	1200	1300	1400	1500
Gas pressure boiler entrance	-.5	-.5	-.5	-.5	-.5	-.5	-.55	-.5
Gas pressure leaving boiler	-2	-2.1	-1.9	-2	-2	-2	-2	-2
Pres. exit dust collector	-4	-4	-3.6	-3.6	-3.6	-3.6	-4	-3.5
Overfire air pressure	32	32	32	32	32	32	31	32
Hearth air pressure	32	32	32	32	32	32	31	32
Grate air pressure	0	0	0	0	0	0	0	0
Charge counts	185	209	225	244	262	281	308	3
ID fan current (amp)	57	57	56	56	57	56	57	56
Steam integrator	X	X	X	X	X	X	X	X
Load cell weight (tons)	8.25	9.19	10.33	11.40	12.57	13.64	13.99	14.94
Primary temperature (°F)	825	1150	970	900	900	1250	1060	1350
Secondary temperature (°F) #TS-2	1460	1600	1560	1550	1460	1660	1660	1600
Fuel oil 1 (gal) Primary	220	220	220	220	220	220	220	220
Waste oil 1 (gal) Primary	15615	15615	15615	15615	15615	15615	15615	15615
Fuel oil 2 (gal) Secondary	326	326	326	326	326	326	326	326
Waste oil 2 (gal) Secondary	203509	203579	203643	203710	203782	203851	203906	203951
Makeup water No. 1 (gal) x 100	16693	16706	16720	16732	16746	16759	16773	16784
Makeup water No. 2 (gal) x 100	17257	17257	17257	17257	17257	17257	17257	17257
Feed water (gal) x 100	48230	48244	48259	48273	48290	48303	48319	48331
Continuous blowdown (gal) x 10	23012	23022	23033	23043	23054	23065	23077	23085
Continuous blowdown (gal)	X	X	X	X	X	X	X	X
Steam pressure (psig)	150	180	152	160	160	190	170	140
Steam calorimeter, temp. (°F)	-	-	279	-	-	-	-	-
Feed water temperature (°F)	180	180	180	180	180	180	180	180
Makeup water temperature (°F)	75	75	78	80	80	80	80	80
Blowdown temperature (°F)	120	100	135	115	96	130	120	100
Ambient temperature (°F)	70	75	80	80	80	80	80	80
Boiler outlet temperature (°F)	460	490	470	460	470	500	465	465
Flue gas O_2 (percent)	20	18.5	18.3	20	20.5	18.5	20.5	19
CO_2 (percent)	1.2	2.4	2.2	1.6	1.6	3.1	1.6	2.6
CO (ppm)	10	10	10	10	10	5	10	5

HOURLY PROCESS DATA

Date 12/8/80

Time	1600	1700	1815	1900	2000	2100+	2200	2300
Gas pressure boiler entrance	-.5	-.5	-.65	-.6	-.5	-.65	-.65	-.60
Gas pressure leaving boiler	-1.7	-1.8	-2.2	-1.9	-1.9	-2.2	-2.1	-2.0
Pres. exit dust collector	-3.5	-3.5	-4.5	-4.1	-3.6	-4.5	-4.4	-4.0
Overfire air pressure	31	31	31	31	31	31	31	31
Hearth air pressure	30	31	31	31	31	31	31	31
Grate air pressure (draft)	0	0	0	0	0.1	0	01(-.3)	01(-.3)
Charge counts	358	377	396	405	427	440	455	472
ID fan current (amp)	55	55	58	56	56	58	57	56
Steam integrator	X	X	X	X	X	X	X	X
Load cell weight (tons)	16.18	17.30	18.72	19.95	20.97	22.72	23.81	24.93
Primary temperature (°F)	900	900	1420	1170	980	1250	1320	1100
Secondary temperature (°F)#TS-2	1440	1440	1640	1580	1460	1580	1590	1540
Fuel oil 1 (gal) Primary	220	220	220	220	220	220	220	220
Waste oil 1 (gal) Primary	15615	15615	15615	15615	15615	15615	15615	15615
Fuel oil 2 (gal) Secondary	326	326	326	326	326	326	326	326
Waste oil 2 (gal) Secondary	204009	204054	204120	204164	204209	204254	204302	204351
Makeup water No. 1 (gal) x 100	16798	16800	16825	16837	16848	16860	16873	16886
Makeup water No. 2 (gal) x 100	17256	17256	17256	17256	17256	17256	17256	17256
Feed water (gal) x 100	48347	48359	48377	48390	48403	48417	48431	48446
Continuous blowdown (gal) x 10	23096	23105	23116	23123	23132	23141	23151	23160
Continuous blowdown (gal)	X	X	X	X	X	X	X	X
Steam pressure (psig)	150	-	-	-	-	-	-	150
Steam calorimeter, temp. (°F)	280	-	-	-	-	-	-	284
Feed water temperature (°F)	180	180	185	180	180	180	180	185
Makeup water temperature (°F)	80	80	80	80	80	80	80	80
Blowdown temperature (°F)	100	100	98	118	110	100	110	120
Ambient temperature (°F)	80	80	80	80	80	80	80	80
Boiler outlet temperature (°F)	460	445	470	470	460	470	470	470
Flue gas O_2 (percent)		18	18.4	19	18	18.75	18.3	18.4
CO_2 (percent)		2.8	2.2	2.2	2.8	2.2	2.2	2.1
CO (ppm)		10	0	10	10	10	10	15

HOURLY PROCESS DATA

Date 12/9/80

Time	0000	0100	0200	0300	0400	0500	0600	0700
Gas pressure boiler entrance	-.5	-.5	-.5	-.45	-.4	-.45	-.45	-.35
Gas pressure leaving boiler	-1.9	-1.9	-1.8	-1.6	-1.6	-1.7	-1.6	-1.5
Pres. exit dust collector	-3.6	-3.5	-3.6	-3.1	-3.1	-3.3	-3	-3.8
Overfire air pressure	31	31	31	31	31	32	31	31
Hearth air pressure	31	31	31	31	31	32	31	31
Grate air pressure	0.1(-.1)	0(-.2)	0(-.2)	0.1(-.2)	.1	.2	.1	.1
Charge counts	490	503	523	540	559	574	587	602
ID fan current (amp)	56	55	54	54	54	55	54	53
Steam integrator	X	X	X	X	X	X	X	X
Load cell weight (tons)	25.77	26.73	27.94	28.93	29.78	30.84	31.87	32.75
Primary temperature (°F)	1100	1060	1340	1100	1100	1150	1280	1080
Secondary temperature (°F)#TS-2	1520	1520	1640	1540	1560	1520	1640	1600
Fuel oil 1 (gal) Primary	220	220	220	220	220	220	220	220
Waste oil 1 (gal) Primary	15615	15615	15615	15615	15615	15615	15615	15615
Fuel oil 2 (gal) Secondary	326	326	326	326	326	326	326	326
Waste oil 2 (gal) Secondary	204394	204445	294494	204538	204591	204633	204679	204724
Makeup water No. 1 (gal) x 100	16897	16911	16924	16924	16924	16924	16924	16924
Makeup water No. 2 (gal) x 100	17256	17256	17257	17269	17283	17293	17304	17315
Feed water (gal) x 100	48459	48475	48491	49503	48519	48531	48543	48556
Continuous blowdown (gal) x 10	23169	23178	23188	23196	23206	23213	23222	23230
Continuous blowdown (gal)	X	X	X	X	X	X	X	X
Steam pressure (psig)	-	-	-	-	-	-	150	150
Steam calorimeter, temp. (°F)	-	-	-	-	-	-	-	281
Feed water temperature (°F)	180	185	175	180	175	180	180	180
Makeup water temperature (°F)	80	80	80	80	80	80	80	80
Blowdown temperature (°F)	120	100	95	95	90	100	125	100
Ambient temperature (°F)	80	80	80	80	80	80	80	80
Boiler outlet temperature (°F)	465	465	465	450	460	460	460	465
Flue gas O_2 (percent)	17.5	18	18.2	18.0	17.4	17.6	18	17.5
CO_2 (percent)	3	3.2	2.8	2.6	4.0	3.8	2.2	3.4
CO (ppm)	10	10	15	10	15	10	15	5

HOURLY PROCESS DATA

Date 12/09/80

Time	0800	0900	1010	1100	1200	1300	1400	1500
Gas pressure boiler entrance	-.5	-.65	-.55	-.6	-.5	-.55	-.5	-.5
Gas pressure leaving boiler	-1.8	-2.1	-2.0	-2.1	-1.8	-1.8	-1.6	-1.6
Pres. exit dust collector	-3.5	-4.0	-3.5	-4.0	-3.5	-3.5	-3	-3
Overfire air pressure	31	31	31	31	31	31	31	31
Hearth air pressure	31	31	31	31	31	31	31	31
Grate air pressure	.1	0	0	0	0	0	0	0
Charge counts	617	634	655	670	684	694	708	722
ID fan current (amp)	54	56	55	55	54	54	53	54
Steam integrator	X	X	X	X	X	X	X	X
Load cell weight (tons)	33.56	34.94	36.28	37.16	38.67	39.69	41.08	41.95
Primary temperature (°F)	1100	1230	1450	1550	1400	1150	1250	1310
Secondary temperature (°F)	1520	[illegible]	1660	1660	1640	1600	1640	1640
Fuel oil 1 (gal) Primary	220	220	220	220	220	220	220	220
Waste oil 1 (gal) Primary	15,615	15,615	15,615	15,615	15,615	15,615	15,615	15,615
Fuel oil 2 (gal) Secondary	326	326	326	326	326	326	326	326
Waste oil 2 (gal) Secondary	204,776	204,820	204,875	204,915	204,960	205,008	205,055	205,102
Makeup water No. 1 (gal) x 100	16,924	16,924	16,924	16,924	16,924	16,924	16,924	16,924
Makeup water No. 2 (gal) x 100	17,329	17,341	17,356	17,366	17,377	17,391	17,402	17,413
Feed water (gal) x 100	48,572	48,585	48,601	48,613	48,626	48,641	48,653	48,666
Continuous blowdown (gal) x 10	23,241	23,250	23,261	23,269	23,278	23,288	23,297	23,307
Continuous blowdown (gal)	X	X	X	X	X	X	X	X
Steam pressure (psig)	160	160	160	160	175	150	165	155
Steam calorimeter, temp. (°F)	-	287	-	-	-	-	-	285
Feed water temperature (°F)	180	180	180	180	180	180	180	180
Makeup water temperature (°F)	80	80	80	80	80	80	80	80
Blowdown temperature (°F)	100	100	90	95	100	95	150	150
Ambient temperature (°F)	80	80	80	80	86	85	85	85
Boiler outlet temperature (°F)	470	470	475	490	475	470	470	470
Flue gas O_2 (percent)		-		-	9.8	11.40	11.5	11.75
CO_2 (percent)		-		-	8.8	7.6	6.2	7.4
CO (ppm)		-		-	10	10	10	20

HOURLY PROCESS DATA

Date 12/09/80

Time	1600	1700	1800	1900	2000	2100	2200	2300
Gas pressure boiler entrance	-.5	-.55	-.5	-.5	-05	-.5	-.55	-.45
Gas pressure leaving boiler	-1.7	-2	-1.4	-1.6	-1.8	-1.7	-1.8	-1.7
Pres. exit dust collector	-3.1	-3.5	-3	-3	-3.5	-3.1	-3.5	-3.1
Overfire air pressure	31	31	31	31	31	31	31	31
Hearth air pressure	31	31	31	31	31	31	31	31
Grate air pressure	.2	.1	0	.1	0(-.25)	0(-.25)	0.4(.1)	0(-.2)
Charge counts	739	750	759	769	781	797	811	823
ID fan current (amp)	53	54	54	54	55	54	55	54
Steam integrator	X	X	X	X	X	X	X	X
Load cell weight (tons)	42.79	43.58	44.47	45.54	46.40	47.68	48.42	49.30
Primary temperature (°F)	1400	1200	1200	1150	1180	1030	930	890
Secondary temperature (°F)	1600	1500	1620	1600	1600	1530	1460	1430
Fuel oil 1 (gal) Primary	unch.	unch.	unch.	unch.	unch.	unch.	unch.	unch.
Waste oil 1 (gal) Primary	unch.	unch.	unch.	unch.	unch.	unch.	unch.	unch.
Fuel oil 2 (gal) Secondary	unch.	unch.	unch.	unch.	unch.	unch.	unch.	unch.
Waste oil 2 (gal) Secondary	205,151	205,197	205,246	205,292	205,345	205,390	205,436	205,487
Makeup water No. 1 (gal) x 100	16,924	16,924	16,924	16,924	16,924	16,924	16,924	16,924
Makeup water No. 2 (gal) x 100	17,426	17,437	17,450	17,462	17,476	17,487	17,498	17,510
Feed water (gal) x 100	48,680	48,693	48,708	48,722	48,739	48,751	48,763	48,777
Continuous blowdown (gal) x 10	23,316	23,325	23,336	23,346	23,356	23,365	23,373	23,382
Continuous blowdown (gal)	X	X	X	X	X	X	X	X
Steam pressure (psig)	175	150	185	155	155	140	150	140
Steam calorimeter, temp. (°F)	-	-	-	-	-	-	-	280
Feed water temperature (°F)	180	180	180	180	185	180	180	185
Makeup water temperature (°F)	80	80	80	80	80	80	80	75
Blowdown temperature (°F)	140	130	110	120	100	130	120	95
Ambient temperature (°F)	85	83	80	80	80	80	80	78
Boiler outlet temperature (°F)	480	470	500	480	475	460	470	460
Flue gas O_2 (percent)	10		11.7	14.0	14.8	13.2	11.5	12.4
CO_2 (percent)	9.0		9.4	5.0	7.0	6.0	8.2	6.6
CO (ppm)	20		20	15	15	20	25	28

HOURLY PROCESS DATA

Date 12/10/80

Time	0000	0100+	0200	0300	0400	0500	0600	0700
Gas pressure boiler entrance	-.45	-.55	-.5	-.4	-.45	-.75	-.45	-.45
Gas pressure leaving boiler	-1.7	-1.8	-1.8	-1.6	-1.6	-	-1.8	-1.
Pres. exit dust collector	-3.2	-3.5	-3.3	-3.1	-3.0		-3.1	-3
Overfire air pressure	31	31	31	31	31		31	31
Hearth air pressure	31	31	31	31	31		31	31
Grate air pressure	0.1(.15)	0(.15)	0(-.2)	.2(.1)	0(-.2)		.1	.1
Charge counts	848	861	876	893	915		965	982
ID fan current (amp)	56	55	56	54	54		54	54
Steam integrator	X	X	X	X	X	X	X	X
Load cell weight (tons)	49.74	50.51	51.24	52.27	53.22	54.37	55.56	56.26
Primary temperature (°F)	1450	1420	1050	1050	830	1200		1250
Secondary temperature (°F)#TS-2	1600	1630	1520	1520	1320	1580		1580
Fuel oil 1 (gal) Primary								
Waste oil 1 (gal) Primary								
Fuel oil 2 (gal) Secondary								
Waste oil 2 (gal) Secondary	205536	205599	205625	205680	205723	205810		205860
Makeup water No. 1 (gal) x 100	16924	16924	16924	16924	16924		16934	169
Makeup water No. 2 (gal) x 100	17522	17538	17544	17558			17580	17580
Feed water (gal) x 100	48789	48808	48817	48831	48843		48868	48802
Continuous blowdown (gal) x 10	23390	23400	23404	23412	23417		23428	23453
Continuous blowdown (gal)	X	X	X	X	X	X	X	X
Steam pressure (psig)	160	160	145	145	140		165	165
Steam calorimeter, temp. (°F)								286
Feed water temperature (°F)	180	185	180	185	180		180	180
Makeup water temperature (°F)	80	80	75	80	80		80	80
Blowdown temperature (°F)	120	120	90	100	90		110	110
Ambient temperature (°F)	75	75	75	80	80		75	75
Boiler outlet temperature (°F)	480	470	470	460	450		470	470
Flue gas O_2 (percent)	11.7	12.5	10.3	12.5	14.7		11.9	11.9
CO_2 (percent)	7	6.4	8.5	6.	5.5		6.8	7.2
CO (ppm)	30	30	30	30	30		30	0

HOURLY PROCESS DATA

Date 12/10/80

Time	0800	0900	1000	1100	1200	1300	1350	1500
Gas pressure boiler entrance	-.6	-.50	-.5	-.4	-.45	-.4	-.4	-.5
Gas pressure leaving boiler	-2	-1.8	-1.8	-1.4	-1.4	-2.1	-1.4	-1.6
Pres. exit dust collector	-3.8	-3.5	-3.3	-2.8	-2.6	-4	-3	-3
Overfire air pressure	31	31	31	31	31	31	31	31
Hearth air pressure	31	31	31	31	31	31	31	31
Grate air pressure	.1	.1	.1	.1	.1	.1	.1	.1
Charge counts	1001	1018	1032	1046	1058	1069	1080	1107
ID fan current (amp)	56	54	54	54	53	54	54	53
Steam integrator	X	X	X	X	X	X	X	X
Load cell weight (tons)	57.92	59.16	60.33	61.56	62.62	63.47	63.87	64.78
Primary temperature (°F)	1400	1400	1400	1300	1300	1260	880	1150
Secondary temperature (°F)#TS-2	1660	1660	1650	1600	1640	1620	1440	1560
Fuel oil 1 (gal) Primary	220	220	220	220	220	220	220	220
Waste oil 1 (gal) Primary	15615	15615	15615	15615	15615	15615	15615	15615
Fuel oil 2 (gal) Secondary	326	326	326	326	326	326	326	326
Waste oil 2 (gal) Secondary	205907	205955	205998	206045	206093	206137	206182	206236
Makeup water No. 1 (gal) x 100	16959	16974	16981	17000	17013	17026	17037	17049
Makeup water No. 2 (gal) x 100	17580	17580	17580	17580	17580	17580	17580	17580
Feed water (gal) x 100	48897	48913	48928	48942	48957	48971	48985	48998
Continuous blowdown (gal) x 10	23438	23454	23468	23479	23490	23499	23507	23515
Continuous blowdown (gal)	X	X	X	X	X	X	X	X
Steam pressure (psig)	175	175	150	165	170	175	130	140
Steam calorimeter, temp. (°F)	-	-	-	-	-	-	-	284
Feed water temperature (°F)	180	180	180	180	180	180	180	180
Makeup water temperature (°F)	80	80	80	80	80	80	80	80
Blowdown temperature (°F)	130	120	110	110	130	140	120	130
Ambient temperature (°F)	80	80	80	80	80	80	80	80
Boiler outlet temperature (°F)	480	490	470	460	490	480	440	460
Flue gas O_2 (percent)	10.			15.75	9.25	10.0	15.7	15.2
CO_2 (percent)	8.2			4.4	10.3	9.0	4.7	5.2
CO (ppm)	0			0	5	10	5	5

HOURLY PROCESS DATA

Date 12/10/80

Time	1600	1700	1800	1900	2000	2100	2200	2300
Gas pressure boiler entrance	-.5	-.5	-.45	-.5	-.55	-.45	-.4	-.45
Gas pressure leaving boiler	-1.7	-1.9	-1.8	-1.9	-2.0	-1.8	-1.6	-[illegible]
Pres. exit dust collector	-3.2	-3.5	-3.5	-3.6	-3.7	-3.3	-3.0	-3.4
Overfire air pressure	30	31	31	31	32	32	32	32
Hearth air pressure	31	31	31	31	32	32	32	32
Grate air pressure	.1	.1	.2	.2	0	0.1	0.1	0.1
Charge counts	1127	1140	1155	1166	1180	1199	1213	1230
ID fan current (amp)	54	53	54	54	54	54	56	54
Steam integrator	X	X	X	X	X	X	X	X
Load cell weight (tons)	65.82	66.88	68.10	69.44	70.14	71.27	72.00	73.24
Primary temperature (°F)	1250	1450	1050	1320	950	1050	940	1020
Secondary temperature (°F)	1600	1650	1520	1660	1570	1520	1480	1500
Fuel oil 1 (gal) Primary	220	220	-	-	-	220	-	-
Waste oil 1 (gal) Primary	15,615	15,615	-	-	-	15,615	-	-
Fuel oil 2 (gal) Secondary	326	326	-	-	-	326	-	-
Waste oil 2 (gal) Secondary	206,283	206,325	206,379	206,437	206,509	206,556	206,598	206,650
Makeup water No. 1 (gal) x 100	17,062	17,074	17,087	17,098	17,111	17,122	17,131	17,143
Makeup water No. 2 (gal) x 100	17,580	17,580	17,580	17,580	17,580	17,580	17,580	17,580
Feed water (gal) x 100	49,013	49,026	49,041	49,054	49,070	49,082	49,092	49,107
Continuous blowdown (gal) x 10	23,523	23,530	23,537	23,540	23,545	23,550	23,554	23,558
Continuous blowdown (gal)	X	X	X	X	X	X	X	X
Steam pressure (psig)	165	175	165	187	170	155	140	150
Steam calorimeter, temp. (°F)	-	-	-	-	-	-	-	285
Feed water temperature (°F)	180	180	180	180	180	180	180	185
Makeup water temperature (°F)	80	80	80	85	80	80	80	80
Blowdown temperature (°F)	115	120	120	95	110	100	100	90
Ambient temperature (°F)	85	85	85	85	80	80	80	80
Boiler outlet temperature (°F)	470	480	470	450	465	465	450	460
Flue gas O_2 (percent)			11.7	9.3	11.5	12	14.5	14.4
CO_2 (percent)			8	9.4	6.6	7.2	5.7	5.8
CO (ppm)			20	20	15	20	35	35

HOURLY PROCESS DATA

Date 12/11/80

Time	0000	0100	0200	0300	0400	0500	0605	
Gas pressure boiler entrance	.45	-.5	-.6	-.55	-.6	-.5	-.5	
Gas pressure leaving boiler	-1.8	-1.7	-2	-1.6	-2.2	-1.6	-2	
Pres. exit dust collector	-3.5	-3.5	-3.8	-3	-4.0	-3	-4	
Overfire air pressure	32	31	31	31	31	31	31	
Hearth air pressure	32	31	31	31	31	31	31	
Grate air pressure	.1	.1	.1	.1	.1	.1	.1	
Charge counts	1247	1261	1277	1290	1307	1322	1332	
ID fan current (amp)	55	54	55	56	55	54	57	
Steam integrator	X	X	X	X	X	X	X	X
Load cell weight (tons)	74.11	74.83	76.25	77.38	78.64	80.02	80.02	
Primary temperature (°F)	900	1300	1400	970	1270	1270	720	
Secondary temperature (°F)	1400	1600	1650	1480	1600	1630	1280	
Fuel oil 1 (gal) Primary	220	220	220	220	220	220	220	
Waste oil 1 (gal) Primary	15,615	15,615	15,615	15,615	15.615	15,615	15,615	
Fuel oil 2 (gal) Secondary	326	326	326	326	326	326	326	
Waste oil 2 (gal) Secondary	206,695	206,737	206,786	206,832	206,878	206,927	206,980	
Makeup water No. 1 (gal) x 100	17,153	17,165	17,178	17,190	17,202	17,215	17,228	
Makeup water No. 2 (gal) x 100	17,580	17,580	17,580	17,580	17,580	17,580	17,580	
Feed water (gal) x 100	49,118	49,131	49,146	49,160	49,173	49,186	49,203	
Continuous blowdown (gal) x 10	23,562	23,566	23,574	23,580	23,585	23,591	23,597	
Continuous blowdown (gal)	X	X	X	X	X	X	X	X
Steam pressure (psig)	148	190	185	150	170	160	125	
Steam calorimeter, temp. (°F)	-	-	-	-	285	-	-	
Feed water temperature (°F)	175	180	180	180	180	180	180	
Makeup water temperature (°F)	80	80	80	80	80	80	80	
Blowdown temperature (°F)	85	110	90	100	110	110	100	
Ambient temperature (°F)	80	80	80	80	80	80	80	
Boiler outlet temperature (°F)	440	475	485	450	480	475	440	
Flue gas O_2 (percent)	7.5		12.0	15	10	12.7		
CO_2 (percent)	12.7		7.6	5.4	9.2	8.4		
CO (ppm)	48		55	55	70	70		

SURFACE TEMPERATURES

Date 12/09/80

Location	Temperature °F
Lower secondary side	180, 250, 200, 260, 250
Lower secondary end	180, 180
Lower secondary side	220, 270
Center afterburner side	280, 300
Lower dump stack	200, 180
Boiler inlet duct	325, 300
Lower grate section side	175, 170, 160, 170
Lower grate end	180
Lower grate section side	175, 190
Hearth side	120, 120
Upper grate side	170, 160, 175, 200
Hearth top	150
Upper afterburner	260
Boiler inlet end	235, 250, 220, 260
Boiler side (both)	130, 130, 140, 130
Boiler outlet end	140, 145, 150
D.A. tank surface	115, 145

Average ________

INTERMITTENT BLOWDOWN

Each blowdown was carried out over 30 seconds

Date	Time	Date	Time	Date	Time	Date	Time
8 Dec	1 a.m.	9 Dec	1 a.m.	10 Dec	1 a.m.	11 Dec	1 a.m.
"	2 a.m.	"	2 a.m.	"	2 a.m.	"	2 a.m.
"	4 a.m.	"	3 a.m.	"	3 a.m.	"	3 a.m.
"	5 a.m.	"	4 a.m.	"	4 a.m.	"	4 a.m.
"	6 a.m.	"	5 a.m.	"	5 a.m.	"	5 a.m.
"	7 a.m.	"	6 a.m.	"	6 a.m.	"	6 a.m.
"	8 a.m.	"	7 a.m.	"	7 a.m.		
"	9 a.m.	"	8 a.m.	"	8 a.m.		
"	10 a.m.	"	9 a.m.	"	9 a.m.		
"	11 a.m.	"	10 a.m.	"	10 a.m.		
"	12 noon	"	11 a.m.	"	11 a.m.		
"	1 p.m.	"	12 noon	"	12 noon		
"	2 p.m.	"	1 p.m.	"	1 p.m.		
"	3 p.m.	"	2 p.m.	"	2 p.m.		
"	4 p.m.	"	3 p.m.	"	3 p.m.		
"	5 p.m.	"	4 p.m.	"	4 p.m.		
"	6 p.m.	"	5 p.m.	"	5 p.m.		
"	7 p.m.	"	6 p.m.	"	6 p.m.		
"	8 p.m.	"	7 p.m.	"	7 p.m.		
"	9 p.m.	"	8 p.m.	"	8 p.m.		
"	10 p.m.	"	9 p.m.	"	9 p.m.		
"	11 p.m.	"	10 p.m.	"	10 p.m.		
"	12 p.m.	"	11 p.m.	"	11 p.m.		
"	–	"	12 p.m.	"	12 p.m.		
"	–		–		–		

AVERAGE DAILY OPERATING CONDITIONS

	Mon	Tue	Wed	Thur	Fri	Average	Total
Temperatures (°F)	8 Dec	9 Dec	10 Dec				
Makeup water	80	80	80			80	
Feedwater	181	180	180			180	
Blowdown	108	110	110			109	
Ambient	81	76	80			80	
Primary	996	1193	1173			1121	
Secondary	1494	1578	1557			1543	
Boiler outlet	463	470	467			467	
Stack	427	434	439			433	
Steam	281	283	285			283	
Steam pressure (psig)	149	158	160			156	
Steam enthalpy (Btu/lb)	1185	1187	1188			1187	
Makeup water flow (10^3 lb)	242	234	308			241	784
Continous blowdown (10^3 lb)	19.1	17.7	17.3			16.9	54.2
Intermittent blowdown (10^3 lb)	23.9	25.0	31.3			24.7	80.2

PARTICULATE SUMMARY DATA SHEET

Location NS Mayport HRI

General					
Date	12/08/80	12/09/80	12/09/80		
Barometric pressure (in. Hg)	30.2	30.2	30.2		
Gas Flow Data					
Stack area (ft^2)	12.05	12.05	12.05		
Average velocity at stack conditions (FPM)	1,188	1,095	1,191		
Flow rate at Stack Conditions (CFM)	14,315	13,195	14,357		
Stack temperature (°F)	440	440	440		
Flow rate at Standard Conditions (SCFM)	8,509	7,843	8,534		
Particulate Emission Data					
Total particulate collected (mg)	544.7	807.3	919.7		
Volume dry gas sampled at Std. Cond. (SCF)	29.24	57.82	56.96		
Total sampled volume at Std. Cond. (SCF)	30.62	61.61	60.75		
Particulate concentration (gr/SCF),(gr/SCF*)	.287(.574)	.215(.487)	.249(.564)		
Particulate emission rate (lb/hr)	19.97	13.56	17.04		
Particulate emission rate (lb/10^6 Btu)	1.14	.775	.974		
Percent isokinetic sample (percent)	43.0	93.9	85.0		
Gas Composition Data					
CO_2 (percent)	6.0	5.3	5.3		
O_2 (percent)	12.3	13.1	13.1		
CO (percent)	**	<.01	<.01		
NO_x (ppm)	**	**	**		
SO_x (ppm)	**	27	27		
HC (ppm)	**	**	**		
Cl (ppm)	131	109	146		

* Corrected to 12% Co_2 .

** Not measured .

PARTICULATE SUMMARY DATA SHEET

Location NS Mayport HRI

General					
Date	12/09/80	12/10/80	12/10/80		
Barometric pressure (in. Hg)	30.2	30.2	30.2		
Gas Flow Data					
Stack area (ft^2)	12.05	12.05	12.05		
Average velocity at stack conditions (FPM)	1,194	1,109	1,211		
Flow rate at Stack Conditions (CFM)	14,387	13,362	14,590		
Stack temperature (°F)	440	440	440		
Flow rate at Standard Conditions (SCFM)	8,552	7,942	8,673		
Particulate Emission Data					
Total particulate collected (mg)	800.1	1296.5	1462.9		
Volume dry gas sampled at Std. Cond. (SCF)	60.13	64.20	64.54		
Total sampled volume at Std. Cond. (SCF)	64.86	69.89	69.75		
Particulate concentration (gr/SCF),(gr/SCF*)	.205(.464)	.311(.868)	.349(.97[illegible]		
Particulate emission rate (lb/hr)	13.92	19.44	24.00		
Particulate emission rate (lb/10^6 Btu)	0.796	1.11	1.37		
Percent isokinetic sample (percent)	94.6	105.2	96.4		
Gas Composition Data					
CO_2 (percent)	5.3	4.3	4.3		
O_2 (percent)	13.1	15.4	15.4		
CO (percent)	<.01	<.01	<.01		
NO_x (ppm)	**	**	**		
SO_x (ppm)	27	24	24		
HC (ppm)	**	**	**		
Cl (ppm)	131	134	153		

* Corrected to 12% Co_2.

** Not measured.

PARTICULATE SUMMARY DATA SHEET

Location NS Mayport HRI

General					
Date	12/11/80	12/11/80	12/11/80		
Barometric pressure (in. Hg)	30.2	30.2	30.2		
Gas Flow Data					
Stack area (ft^2)	12.05	12.05	12.05		
Average velocity at stack conditions (FPM)	1,019	1,127	1,083		
Flow rate at Stack Conditions (CFM)	12,277	13,580	13,055		
Stack temperature (°F)	440	440	440		
Flow rate at Standard Conditions (SCFM)	7,298	8,072	7,760		
Particulate Emission Data					
Total particulate collected (mg)	763.2	1302.8	849.2		
Volume dry gas sampled at Std. Cond. (SCF)	55.55	63.11	60.08		
Total sampled volume at Std. Cond. (SCF)	61.24	68.32	64.82		
Particulate concentration (gr/SCF),(gr/SCF*)	.212(.591)	.318(.887)	.218(.608)		
Particulate emission rate (lb/hr)	12.02	20.31	13.42		
Particulate emission rate (lb/10^6 Btu)	.687	1.16	.767		
Percent isokinetic sample (percent)	103	101.2	100.1		
Gas Composition Data					
CO_2 (percent)	4.3	4.3	4.3		
O_2 (percent)	15.4	15.4	15.4		
CO (percent)	<.01	<.01	<.01		
NO_x (ppm)	**	**	**		
SO_x (ppm)	24	24	24		
HC (ppm)	**	**	**		
Cl (ppm)	176	77	167		

* Corrected to 12% Co_2.

** Not measured.

CHLORIDES ANALYSIS

Plant NS Mayport HRI
Boiler
Location

Date 12/09/80 through 12//2/80
Analyst
Run No.

Chloride mg/ℓ = C ppm
Dilution factor = D
Total Volume of Sample Solutuion = M (mℓ)
Meter Temperature = t (°C)*
Barometric pressure in stack = P (mm Hg)*
Volume of air sampled = V (ℓ)
Aliquot volume analyzed = m (mℓ)

$$\text{mg Cl/m}^3 \text{ @ } 20°\text{C} = \frac{(C)\ (D)\ (M)\ (t+273)\ (760)\ (1000)}{(1000)\ (P)\ (V)\ (293)}$$

$$\text{ppm Cl} = (0.690)\ (\text{mg Cl/m}^3) \text{ @ } 20°\text{C}$$

SAMPLE	m	C	D	M	t	P	V	Cl mg/m^3	Cl ppm
M5 - 1	50	625	1	264	20	760	867	190	131
M5 - 2	50	1010	1	273	20	760	1744	158	109
M5 - 3	50	1290	1	282	20	760	1720	212	146
M5 - 4	50	1310	1	267	20	760	1837	190	137
M5 - 5	50	1300	1	295	20	760	1979	194	134
M5 - 6	50	1420	1	309	20	760	1975	222	153
M5 - 7	50	1330	1	332	20	760	1734	255	176
M5 - 8	50	794	1	271	20	760	1935	111	77
M5 - 9	50	1490	1	298	20	760	1836	242	167

Mass and Energy Balances

and Performance Calculations

COMPOSITE ULTIMATE ANALYSIS*

	Solid waste	Waste oil	Monday 12/8/80	Tuesday 12/9/80	Wednesday 12/10/80
Solid waste (lb)	---	---	51,520	47,980	60,460
Waste oil (lb)	---	---	9,611	7,531	9,949
C (%)	29.02	86	37.98	36.84	37.07
H (%)	3.84	12	5.12	4.95	4.99
O (%)	20.38	0	17.18	17.62	17.50
N (%)	0.61	1	0.67	0.66	0.67
Cl (%)	0.56	0	0.47	0.48	0.48
S (%)	0.17	0.5	0.22	0.21	0.22
I (%)	20.39	0.5	17.26	17.69	17.58
H_2O (%)	25.00	0	21.07	21.61	21.47

* As-received basis.

Flue Gas Composition - Boiler Outlet

Average of periodic readings (every 15 minutes) from continuous monitors.

Date	12/9/80	12/10/80	Average
Time period (hrs)	12	30	
CO_2 (%)	6.99	7.76	7.5
Standard deviation	1.73	2.45	
O_2 (%)	13.20	12.54	12.7
Standard deviation	2.03	2.64	
CO (ppm)	25	71	58
Standard deviation	--	--	

Flue Gas Analysis

To determine Stoichiometric Oxygen Requirement

$$O_2 = 2.67\ C_f + 8\ H_f + S_f - O_f$$

Neglecting small amount of carbon in the bottom ash

$$C_f = 37.45,\ H_f = 5,\ O_f = 17.4,\ S_f = 0$$

$$O_2 = 1.00 + .40 + .002 - .174 = 1.224\ \frac{\text{lb oxygen}}{\text{lb fuel}}$$

Determination of Stoichiometric Air Requirement

$$SA = \frac{4.32\ \text{lb air}}{\text{lb}\ O_2} \times \frac{1.244\ \text{lb}\ O_2}{\text{lb fuel}} = 5.29\ \frac{\text{lb air}}{\text{lb fuel}}$$

Excess Air Determination

$$EA = 100 \times \frac{O_2 - \frac{CO}{2}}{.2682\ N_2 - (O_2 - \frac{CO}{2})}$$

$$EA = 100 \times \frac{12.7 - 0}{.2682\ (79) - 12.7}$$

$$EA = 150\ \text{percent}$$

Actual Air/Fuel Ratio

$$A/F = SA \times (1 + \frac{EA}{100})$$

$$A/F = 5.29 \times (1 + \frac{150}{100})$$

$$A/F = 13.21\ \frac{\text{lb air}}{\text{lb fuel}}$$

BOILER OPERATION CALCULATIONS

Date 12-8-80

Average temperatures - Daily

Numerical average of 24 hourly readings

Steam pressure - Daily

Numerical average of 24 hourly readings

Steam enthalpy - Daily

Numerical average of 3 daily calorimeter readings as determined from Mollier diagram

Makeup water flow - Daily

Final meter No. 1 reading		16,886	(gal)
Initial meter No. 1 reading	-	16,596	(gal)
Net difference	=	290	(gal)
Meter calibration factor	×	100	
Net volume flowed	=	29,000	(gal)
Water density	×	8.336	(lb/gal)
Input water	=	241.74×10^3	(lb) [M_{17A}]

Final meter No. 2 reading		17256	(gal)
Initial meter No. 2 reading	-	17256	(gal)
Net difference	=	-	(gal)
Meter calibration factor	×	100	
Net volume flowed	=	-	(gal)
Water density	×	8.336	(lb/gal)
Input water	=	-	(lb) [M_{17B}]

(continued)

BOILER OPERATION CALCULATIONS

Date 12-8-80

Total input water = $M_{17A} + M_{17B}$

M_{17} = 241.74x10^3 + - = 241.74x10^3 lb

Continuous blowdown - Daily

Final blowdown meter reading		23,160	(gal)
Initial blowdown meter reading	-	22,930	(gal)
Net difference	=	230	(gal)
Meter calibration factor	×	10	
Net volume	=	2,300	(gal)
Water density	×	8.336	(lb/gal)
Continuous blowdown	=	19.173x10^3	(lb) [M_{19c}]
Total intermittent blowdown	+	23.966x10^3	(lb) [M_{19i}]
Total blowdown	=	43.139x10^3	(lb) [M_{19}]

Steam Generation - Daily reported

Total input water		241.74x10^3	(lb) [M_{17}]
Total blowdown	-	43.139x10^3	(lb) [M_{19}]
Intermittent blowdown line leak	-	1.000x10^3	(lb)
Steam separator line leak	-	1.000x10^3	(lb)
Steam generated	=	190.60x10^3	(lb) [M_{15}]

Heat output - Daily

Heat output = Steam generated × (Steam enthalpy - makeup water enthalpy)

EN out = 196.60x10^3 × (1185 - 48) = 233.53x10^6 (Btu)

(continued)

BOILER OPERATION CALCULATIONS

Date 12-8-80

Steam meter flow - cross check only

Final steam integrator reading		______
Initial steam integrator reading	-	______
Net difference	=	______
Integrator factor	×	______
Integrator steam generated	=	______

Blowdown heat loss calculation

Total blowdown = M_{19} (lb)

Blowdown energy loss = EN_{bd} (Btu)

Enthalpy of blowdown water = h_{bd}

Enthalpy of makeup water = h_{mu}

$$EN_{bd} = M_{19} \times (h_{bd} - h_{mu})$$

$$EN_{bd} = \underline{43,139} \times (\underline{75.98} - \underline{48}) = \underline{1.207 \times 10^6} \text{ Btu}$$

(concluded)

BOILER OPERATION CALCULATIONS

Date 12-9-80

Average temperatures - Daily

Numerical average of 24 hourly readings

Steam pressure - Daily

Numerical average of 24 hourly readings

Steam enthalpy - Daily

Numerical average of 3 daily calorimeter readings as determined from Mollier diagram

Makeup water flow - Daily

Final meter No. 1 reading		16924	(gal)
Initial meter No. 1 reading	-	16897	(gal)
Net difference	=	27	(gal)
Meter calibration factor	x	100	
Net volume flowed	=	2700	(gal)
Water density	x	8.336	(lb/gal)
Input water	=	22.507×10^3	(lb) [M_{17A}]

Final meter No. 2 reading		17,510	(gal)
Initial meter No. 2 reading	-	17,256	(gal)
Net difference	=	245	(gal)
Meter calibration factor	x	100	
Net volume flowed	=	25,400	(gal)
Water density	x	8.336	(lb/gal)
Input water	=	211.73×10^3	(lb) [M_{17B}]

(continued)

Date 12/09/80

Total input water = $M_{17A} + M_{17B}$

M_{17} = 22.50×10^3 + 211.73×10^3 = 234.237×10^3 lb

Continuous blowdown - Daily

Final blowdown meter reading		23382	(gal)	
Initial blowdown meter reading	-	23169	(gal)	
Net difference	=	213	(gal)	
Meter calibration factor	×	10		
Net volume	=	2130	(gal)	
Water density	×	8.336	(lb/gal)	
Continuous blowdown	=	17.756×10^3	(lb)	[M_{19c}]
Total intermittent blowdown	+	25.008×10^3	(lb)	[M_{19i}]
Total blowdown	=	42.764×10^3	(lb)	[M_{19}]

Steam Generation - Daily reported

Total input water		234.237×10^3	(lb)	[M_{17}]
Total blowdown	-	42.764×10^3	(lb)	[M_{19}]
Intermittent blowdown line leak	-	1.000×10^3	(lb)	
Steam separator line leak	-	1.000×10^3	(lb)	
Steam generated	=	189.473×10^3	(lb)	[M_{15}]

Heat output - Daily

Heat output = Steam generated × (Steam enthalpy - makeup water enthalpy)

EN out = 189.473×10^3 × (1187 - 48) = 215.810×10^6 (Btu)

(continued)

Date 12/09/80

Steam meter flow - cross check only

Final steam integrator reading		
Initial steam integrator reading	-	
Net difference	=	
Integrator factor	×	
Integrator steam generated	=	

Blowdown heat loss calculation

Total blowdown = M_{19} (lb)

Blowdown energy loss = EN_{bd} (Btu)

Enthalpy of blowdown water = h_{bd}

Enthalpy of makeup water = h_{mu}

$$EN_{bd} = M_{19} \times (h_{bd} - h_{mu})$$

$$EN_{bd} = 42,764 \times (77.98 - 48) = 1.282 \times 10^6 \text{ Btu}$$

(concluded)

BOILER OPERATION CALCULATIONS (Page 1 of 3)

Date 12-10-80 (includes Thursday to 0600 hrs)

Average temperatures - Daily

Numerical average of 24 hourly readings

Steam pressure - Daily

Numerical average of 24 hourly readings

Steam enthalpy - Daily

Numerical average of 3 daily calorimeter readings as determined from Mollier diagram

Makeup water flow - Daily

Final meter No. 1 reading		17228	(gal)
Initial meter No. 1 reading	-	16924	(gal)
Net difference	=	304	(gal)
Meter calibration factor	×	100	
Net volume flowed	=	30400	(gal)
Water density	×	8.336	(lb/gal)
Input water	=	253.414×10^3	(lb) [M_{17A}]

Final meter No. 2 reading		17580	(gal)
Initial meter No. 2 reading	-	17522	(gal)
Net difference	=	58	(gal)
Meter calibration factor	×	100	
Net volume flowed	=	5800	(gal)
Water density	×	8.336	(lb/gal)
Input water	=	48.349×10^3	(lb) [M_{17B}]

(continued)

Date 12-10-80

Total input water = $M_{17A} + M_{17B}$

$M_{17} = 253.414 \times 10^3 + 48.349 \times 10^3 = 301.763 \times 10^3$ lb

Continuous blowdown - Daily

Final blowdown meter reading		23597	(gal)
Initial blowdown meter reading	-	23390	(gal)
Net difference	=	207	(gal)
Meter calibration factor	×	10	
Net volume	=	2070	(gal)
Water density	×	8.336	(lb/gal)
Continuous blowdown	=	17.256×10^3	(lb) [M_{19c}]
Total intermittent blowdown	+	31.260×10^3	(lb) [M_{19i}]
Total blowdown	=	48.516×10^3	(lb) [M_{19}]

Steam Generation - Daily reported

Total input water		307.763×10^3	(lb) [M_{17}]
Total blowdown	-	48.516×10^3	(lb) [M_{19}]
Steam generated	=		(lb) [M_{15}]
Intem. hont blowdown line leak		1.250×10^3 lb	
Steam Separator line leak		1.250×10^3 lb	
Steam Generated		256.747×10^3 lb	

Heat output - Daily

Heat output = Steam generated × (Steam enthalpy - makeup water enthalpy)

EN out $= 256.747 \times 10^3 \times (1188 - 48) = 292.692 \times 10^6$ (Btu)

(continued)

Date 12-10-80

Steam meter flow - cross check only

Final steam integrator reading		______
Initial steam integrator reading	-	______
Net difference	=	______
Integrator factor	×	______
Integrator steam generated	=	______

Blowdown heat loss calculation

Total blowdown = M_{19} (lb)

Blowdown energy loss = EN_{bd} (Btu)

Enthalpy of blowdown water = h_{bd}

Enthalpy of makeup water = h_{mu}

$$EN_{bd} = M_{19} \times (h_{bd} - h_{mu})$$

$$EN_{bd} = \underline{48{,}516} \times (\underline{77.98} - \underline{48}) = \underline{1.455 \times 10^{6}} \text{ Btu}$$

(concluded)

BOILER OPERATION CALCULATIONS (Page 1 of 3)

Date 8, 9, 10 Dec. 1980

Average temperatures - Daily

Numerical average of 24 hourly readings

Steam pressure - Daily

Numerical average of 24 hourly readings

Steam enthalpy - Daily

Numerical average of 3 daily calorimeter readings as determined from Mollier diagram

Makeup water flow - Daily

Final meter No. 1 reading		17228	(gal)
Initial meter No. 1 reading	-	16596	(gal)
Net difference	=	632	(gal)
Meter calibration factor	×	100	
Net volume flowed	=	63200	(gal)
Water density	×	8.336	(lb/gal)
Input water	=	526,835	(lb) [M_{17A}]

Final meter No. 2 reading		17580	(gal)
Initial meter No. 2 reading	-	17256	(gal)
Net difference	=	324	(gal)
Meter calibration factor	×	100	
Net volume flowed	=	32400	(gal)
Water density	×	8.336	(lb/gal)
Input water	=	270086	(lb) [M_{17B}]

(continued)

BOILER OPERATION CALCULATIONS

Date 8, 9, 10 Dec. 1980

Total input water = $M_{17A} + M_{17B}$

M_{17} = ________ + ________ = 796,921 lb

Continuous blowdown - Daily

Final blowdown meter reading		23597	(gal)
Initial blowdown meter reading	−	22930	(gal)
Net difference	=	667	(gal)
Meter calibration factor	×	10	
Net volume	=	6670	(gal)
Water density	×	8.336	(lb/gal)
Continuous blowdown	=	55601	(lb) [M_{19c}]
Total intermittent blowdown	+	80234	(lb) [M_{19i}]
Total blowdown	=	135835	(lb) [M_{19}]

Steam Generation - Daily reported

Total input water		796921	(lb) [M_{17}]
Total blowdown	−	135921	(lb) [M_{19}]
Steam generated	=		(lb) [M_{15}]
Steam Separator line leak		3250	
Intermittent blowdown line leak		3250	
Steam Generated		654500	

Heat output - Daily

Heat output = Steam generated × (Steam enthalpy − makeup water enthalpy)

EN out = 654500 × (1187 − 48) = 745.476×10^6 (Btu)

(continued)

Date 8, 9, 10 Dec. 1980

Steam meter flow - cross check only

Final steam integrator reading		______
Initial steam integrator reading	-	______
Net difference	=	______
Integrator factor	×	______
Integrator steam generated	=	______

Blowdown heat loss calculation

Total blowdown = M_{19} (lb)

Blowdown energy loss = EN_{bd} (Btu)

Enthalpy of blowdown water = h_{bd}

Enthalpy of makeup water = h_{mu}

$$EN_{bd} = M_{19} \times (h_{bd} - h_{mu})$$

$$EN_{bd} = \underline{135,835} \times (\underline{77.31} - \underline{48}) = \underline{3.98\text{x}10^6} \text{ Btu}$$

(concluded)

Steam Quality Calculations

Keenan and Keyes Steam Tables

Monday, December 8, 1980

at 14.7 psia $T = 281°F$

$h = 1184.0$ Btu/lb

at 149 psig = 163.7 psia $\quad hf = 338.0$, $hg = 1195.5$

$$x = \frac{1195.5 - 1184.0}{1195.5 - 338.0} = 1.3 \text{ or } 98.7$$

Tuesday, December 9, 1980

at 14.7 psia $T = 283$

$h = 1184.7$

at 158 psig = 172.7 psia $\quad hf = 342.5$, $hg = 1196.3$

$$x = \frac{1196.3 - 1184.7}{1196.3 - 342.5} = 1.4 \text{ or } 98.6$$

Wednesday, December 10, 1980

at 14.7 psia $T = 285$

$h = 1185.7$

at 160 psia = 174.7 psig $\quad hf = 343.5$, $hg = 1196.5$

$$x = \frac{1196.5 - 1185.7}{1196.5 - 343.5} = 1.3 \text{ or } 98.7$$

Monday, 12/8/80

BOILER OUTLET GAS CALCULATIONS

TOTAL MOISTURE OUTPUT

Fuel moisture input		$61131 \times .214 = 13082$	(lb)
Total hydrogen formed moisture	+	$9 \times .05 \times 61131 = 27509$	(lb)
Total moisture output	=	40591	(lb) [M_{2Om}]

Moisture weight fraction of flue gas = WF_m

Total flue gas wt. = air wt. + fuel wt. - dry ash wt.

Total flue gas wt. = (13.21 × 61131) + 61131 - 3852 = 864820 (lb)

$$\frac{40591}{864820} = .047 \frac{\text{lb } H_2O}{\text{lb flue gas}}$$

Tuesday, 12/9/80

BOILER OUTLET GAS CALCULATIONS

TOTAL MOISTURE OUTPUT

Fuel moisture input		$\underline{65511 \times .214 = 11879}$	(lb)
Total hydrogen formed moisture	+	$\underline{9 \times .05 \times 55511 = 24980}$	(lb)
Total moisture output	=	$\underline{36859}$	(lb) [M_{2Om}]

Moisture weight fraction of flue gas = WF_m

Total flue gas wt. = air wt. + fuel wt. - dry ash wt.

Total flue gas wt. = (13.21 × 55511) + 55511 - 10575 = 778236 (lb)

$$\frac{36859}{778236} = .047 \frac{\text{lb } H_2O}{\text{lb flue gas}}$$

Wednesday, 12/10/80

BOILER OUTLET GAS CALCULATIONS

TOTAL MOISTURE OUTPUT

Fuel moisture input	$70409 \times .214 = 15067$	(lb)
Total hydrogen formed moisture	+ $9 \times .05 \times 70409 = 31684$	(lb)
Total moisture output	= 46751	(lb) [M_{20m}]

Moisture weight fraction of flue gas = WF_m

Total flue gas wt. = air wt. + fuel wt. - dry ash wt.

Total flue gas wt. = $(13.21 \times 70409) + 70409 - 24035 = 976477$ (lb)

$$\frac{46751}{976477} = .048 \frac{\text{lb } H_2O}{\text{lb flue gas}}$$

TOTAL

BOILER OUTLET GAS CALCULATIONS

TOTAL MOISTURE OUTPUT

Fuel moisture input	187,051 × .214 = 40,029	(lb)
Total hydrogen formed moisture	+ 9 × .05 × 187,051 = 84,173	(lb)
Total moisture output	= 124,202	(lb) [$M_{2}O_{m}$]

Moisture weight fraction of flue gas = WF_m

Total flue gas wt. = air wt. + fuel wt. - dry ash wt.

Total flue gas wt. = (13.21 × 187,051) + 187,051 - 38,462 = 2,619,533 (lb)

$$\frac{124,202}{2,619,533} = .047 \frac{\text{lb } H_2O}{\text{lb flue gas}}$$

BOILER OUTLET GAS CALCULATIONS

SENSIBLE FLUE GAS HEAT   Mon 12/08/80

Gas	1 Mass fraction (lb/lb)	2 M	3 Enthalpy at flue temperature T = 463 (Btu/mole)	4 Enthalpy at ambient temperature T = 81 (Btu/mole)	5 Δh (Btu/mole)	6 Flue gas loss (Btu/lb)
CO_2	.107	44	7813	4065	3748	9.11
O_2	.132	32	6509	3750	2759	11.38
N_2	.715	28	6410	3750	2660	67.93
CO	-	28	-	-	-	-
H_2O	.047	18	22882	882	22000	57.44
Total	1.000	29.80			h Total =	145.86

3 and 4 From Keenan and Kaye Gas Tables and Steam Tables

$5 = 3 - 4$

$6 = \frac{1}{2} \times 5$

$$\text{Percent } H_2O \text{ (by volume)} = \frac{\frac{WF_m}{18}}{\Sigma \frac{1}{2}} \times 100 = \underline{\qquad} \text{ percent}$$

(continued)

BOILER OUTLET GAS CALCULATIONS

SENSIBLE FLUE GAS HEAT Tues 12/09/80

Gas	① Mass fraction (lb/lb)	② M	③ Enthalpy at flue temperature T = 470 (Btu/mole)	④ Enthalpy at ambient temperature T = 76 (Btu/mole)	⑤ Δh (Btu/mole)	⑥ Flue gas loss (Btu/lb)
CO_2	.107	44	7918	4013	3905	9.50
O_2	.132	32	6561	3711	2850	11.76
N_2	.715	28	6480	3716	2764	70.58
CO	-	28	-	-	-	-
H_2O	.047	18	22941	792	22149	57.83
Total	1.000	-	-	-	h Total =	149.67

③ and ④ From Keenan and Kaye Gas Tables and Steam Tables

$⑤ = ③ - ④$

$⑥ = \frac{①}{②} \times ⑤$

$$\text{Percent } H_2O \text{ (by volume)} = \frac{\frac{WF_m}{18}}{\Sigma \frac{①}{②}} \times 100 = \_\_\_\_\_\_ \text{ percent}$$

(continued)

BOILER OUTLET GAS CALCULATIONS

SENSIBLE FLUE GAS HEAT Wed 12/10/80

Gas	① Mass fraction (lb/lb)	② M	③ Enthalpy at flue temperature T = 467 (Btu/mole)	④ Enthalpy at ambient temperature T = 80 (Btu/mole)	⑤ Δh (Btu/mole)	⑥ Flue gas loss (Btu/lb)
CO_2	.107	44	7816	4057	3759	9.14
O_2	.132	32	6539	3746	2793	11.52
N_2	.715	28	6459	3750	2709	69.18
CO	-	28	-	-	-	-
H_2O	.047	18	22916	864	22052	57.58
Total	1.000	-	-	-	h Total =	147.42

③ and ④ From Keenan and Kaye Gas Tables and Steam Tables

$$⑤ = ③ - ④$$

$$⑥ = \frac{①}{②} \times ⑤$$

$$\text{Percent } H_2O \text{ (by volume)} = \frac{\frac{WF_m}{18}}{\Sigma \frac{①}{②}} \times 100 = \_\_\_\_\_\_ \text{ percent}$$

(continued)

BOILER OUTLET GAS CALCULATIONS

SENSIBLE FLUE GAS HEAT - Overall

Gas	(1) Mass fraction (lb/lb)	(2) M	(3) Enthalpy at flue temperature T = 467 (Btu/mole)	(4) Enthalpy at ambient temperature T = 80 (Btu/mole)	(5) Δh (Btu/mole)	(6) Flue gas loss (Btu/lb)
CO_2	.107	44	7816	4057	3759	9.14
O_2	.132	32	6539	3746	2793	11.52
N_2	.715	28	6459	3750	2709	69.18
CO	-	28	-	-	-	-
H_2O	.047	18	22916	864	22052	57.58
Total	1.000	-	-	-	h Total =	147.42

(3) and (4) From Keenan and Kaye Gas Tables and Steam Tables

$(5) = (3) - (4)$

$(6) = \frac{(1)}{(2)} \times (5)$

$$\text{Percent } H_2O \text{ (by volume)} = \frac{\frac{WF_m}{18}}{\Sigma \frac{(1)}{(2)}} \times 100 = \_\_\_\_\_\_ \text{ percent}$$

(continued)

BOILER OUTLET GAS CALCULATIONS

GAS MASS FRACTIONS

Gas	(1) Volume percentage (percent dry weight)	(2) M (lb/mole)	(3) Mole weight portion (lb dry)	(4) Mass fraction (lb/lb, dry weight)	(5) Mass fraction (lb/lb, total weight)
CO_2	7.4	44	3.30	.112	.107
O_2	12.7	32	4.06	.138	.132
N_2	78.9	28	22.09	.750	.715
CO	-	28	-	-	-
H_2O	-	18	-	WF_m =	.047
Total			29.45		1.00

$$(3) = \frac{(1)}{100} \times (2)$$

$$(4) = (3) / (3) \text{ total}$$

$$(5) = (4) \times WF_D$$

(continued)

BOILER OUTLET GAS CALCULATIONS

FLUE GAS ENERGY LOSS

$EN_{stack} = M20 \times h\ Total$

$EN_{stack} = 864{,}820 \times 145.86 = 126.14 \times 10^6$ Btu

FLUE GAS SPECIFIC HEAT

$$C_p = \frac{EN_{stack}}{M20 \times T_{outlet} - T_{amb}}$$

$$C_p = \frac{126 \times 10^6 \text{ (Btu)}}{864 \times 10^3 \text{ (lb)} \times (\ 463\ ^\circ F -\ 81\ ^\circ F)}$$

$C_p =$ .38 Btu/lb °F

Tuesday, 12/9/80

BOILER OUTLET GAS CALCULATIONS

FLUE GAS ENERGY LOSS

$$EN_{stack} = M20 \times h\ Total$$

$$EN_{stack} = 778{,}236 \times 149.67 = 116.48 \times 10^6\ Btu$$

FLUE GAS SPECIFIC HEAT

$$C_p = \frac{EN_{stack}}{M20 \times T_{outlet} - T_{amb}}$$

$$C_p = \frac{116.48\ (Btu)}{778 \times 10^3\ (lb) \times (\ 470\ \ ^\circ F - \ \ 76\ \ ^\circ F)}$$

$$C_p = \ .38 \quad Btu/lb\ ^\circ F$$

Wednesday, 12/10/80

BOILER OUTLET GAS CALCULATIONS

FLUE GAS ENERGY LOSS

$$EN_{stack} = M_{20} \times h\ \text{Total}$$

$$EN_{stack} = 976{,}477 \times 147.42 = 143.95 \times 10^{6}\ \text{Btu}$$

FLUE GAS SPECIFIC HEAT

$$C_p = \frac{EN_{stack}}{M20 \times T_{outlet} - T_{amb}}$$

$$C_p = \frac{143.9 \times 10^{6}\ (\text{Btu})}{976 \times 10^{3}\ (\text{lb}) \times (\ 467\ \ {}^{\circ}F - \ 80\ \ {}^{\circ}F)}$$

$$C_p = .38 \quad \text{Btu/lb}\ {}^{\circ}F$$

BOILER OUTLET GAS CALCULATIONS

FLUE GAS ENERGY LOSS

$$EN_{stack} = M_{20} \times h\ \text{Total}$$

$$EN_{stack} = 2{,}619{,}533 \times 147.42 = 386.17 \times 10^6\ \text{Btu}$$

FLUE GAS SPECIFIC HEAT

$$C_p = \frac{EN_{stack}}{M20 \times T_{outlet} - T_{amb}}$$

$$C_p = \frac{386 \times 10^6\ (\text{Btu})}{2.619 \times 10^6\ (\text{lb}) \times (\ 467\ \ ^\circ\text{F} -\ \ 80\ \ ^\circ\text{F})}$$

$$C_p = \ .38\ \ \text{Btu/lb}\ ^\circ\text{F}$$

Electrical Energy Usage

481 Volts 3 phase

December 9, 1980 - 3:45 p.m.

203 Amps average

$$\sqrt{3}\ \frac{481 \text{ volts} \times 203 \text{ amps}}{1000} = 169.4 \text{ kW}$$

$169.4 \text{ kW} \times 11{,}600 \text{ Btu/kWh*} - 1.965 \times 10^{6} \text{ Btu/hr}$

Diesel Fuel Usage Front-end Loader

57 gal/120 hr = .475 gal/hr (from plant operating experience)

Assumed Properties**

Density = 7.30 lb/gal

HHV = 19,500 Btu/lb

$$\frac{.475 \text{ gal}}{\text{hr}} \times \frac{7.30 \text{ lb}}{\text{gal}} \times \frac{19{,}500 \text{ Btu}}{\text{lb}} = 67{,}590 \text{ Btu/hr}$$

* At 30 percent fuel to electrical energy conversion efficiency.

** Engineering experimentation, p 331.

Metals and EP Toxicity

Quality Assurance Data

QUALITY ASSURANCE DATA FOR
ICP SPECTOSCOPY ANALYSES

Element	Detection Limit, μg/liter	LQD conc.[a] μg/liter
Aluminum	36	180
Antimony	20	100
Barium	0.5	2.5
Beryllium	0.6	3
Boron	4	20
Cadmium	2	10
Calcium	0.8	4
Chromium	3	15
Cobalt	8	40
Copper	4	20
Iron	3	15
Lead	20	100
Magnesium	0.7	3.5
Manganese	0.8	4
Molybedenum	8	40
Nickel	47	235
Phosphorus	40	200
Silicon	18	90
Silver	15	75
Sodium	60	300
Strontium	0.6	3
Tin	13	65
Titanium	2	10
Vanadium	7	35
Zinc	3	15

[a]LQD = lowest quantitatively determinable concentration (95% confidence limits).

QUALITY ASSURANCE DATA FOR EP TOXICITY ANALYSES

	ACTUAL CONCENTRATION (ug/ℓ)	RECORDED CONCENTRATION (ug/ℓ)
Arsenic	20	17
Selenium	20	18
Mercury	2.0	2.1
Silver	1000	960
Cadmium	1000	966
Chromium	1000	933
Barium	2000	1880
Lead	1000	963

	SPIKE (D.I. Water) (ug/ℓ)	RECOVERY (%)
Lindane	10	97
Endrin	10	90
Methoxychlor	10	85
Toxaphene	10	80
2,4-D	4	77
Silvex	4	59

NOVEMBER MASS AND ENERGY

BALANCE CALCULATIONS

NOVEMBER MASS AND ENERGY BALANCE CALCULATIONS

Waste Oil	Tank 1	Tank 2
Mass (lb)	5,223	43,834
Density (lb/gal)	6.89	6.89
Heating value (Btu/lb)	19,704	19,782
Total Input Energy (10^6 Btu)	103.04	867.13

Input Air

$$\text{lb } O_2/\text{lb fuel} = 2.67\ C_f + 8\ H_f + S_f - O_2$$

$$\text{lb } O_2/\text{lb fuel} = 2.30 + .96 + .005 = 3.265$$

$$\text{Stoichiometric air} = \frac{4.32 \text{ lb air}}{\text{lb } O_2} \times \frac{3.265 \text{ lb } O_2}{\text{lb fuel}} = \frac{14.09 \text{ lb air}}{\text{lb fuel}}$$

$$\text{Excess air} = \frac{O_2 - CO/2}{0.2682\ N_2 - (O_2 - CO/2)} = \frac{14.69}{21.53 - 14.69} = 2.15$$

$$\text{lb air/lb fuel} = \frac{14.09 \text{ lb air}}{\text{lb fuel}} (1 + 2.15) = \frac{44.38 \text{ lb air}}{\text{lb fuel}}$$

$$\text{lb air input} = \frac{44.38 \text{ lb air}}{\text{lb fuel}} \times 49{,}057 \text{ lb fuel} = 2.177 \times 10^6 \text{ lb air}$$

Feed Water

Meter 1 469,317 lb

Meter 2 71,690 lb

Heat Output in Steam

$$541{,}000 \text{ lb } (1{,}180 \text{ Btu/lb} - 45 \text{ Btu/lb}) = 614.043 \times 10^6 \text{ Btu}$$

Flue Gas Loss

$$\begin{aligned} \text{Flue gas mass} &= \text{lb air input} + \text{lb fuel input} \\ &= 2.177 \times 10^6 \text{ lb} + 49{,}067 \text{ lb} \\ &= 2.226 \times 10^6 \text{ lb} \end{aligned}$$

$$\text{Flue gas energy} = \text{flue gas (lb)} \times \frac{\text{flue gas enthalpy}}{\text{lb}}$$

GAS MASS FRACTIONS

Gas	① Volume percentage (percent dry weight)	② M (lb/mole)	③ Mole weight portion (lb dry)	④ Mass fraction (lb/lb, dry weight)	⑤ Mass fraction (lb/lb, total weight)
CO_2	5.05	44	2.22	.075	.074
O_2	14.69	32	4.70	.159	.158
N_2	80.26	28	22.47	.764	.760
CO		28			
H_2O		18		WF_m =	.035
Total			29.39		1.027

$$③ = \frac{①}{100} \times ②$$

$$④ = ③ \,/\, ③ \text{ total}$$

$$⑤ = ④ \times WF_D$$

$$WF_m = \frac{9 \times H_F}{\text{Total flue gas}} = \frac{9 \times .18 \times 49057}{2.226 \times 10^6} = .035$$

$$WF_D = \frac{\text{Total flue gas} - (.18 \times 49057)}{\text{Total flue gas}} = .996$$

SENSIBLE FLUE GAS HEAT

Gas	(1) Mass fraction (lb/lb)	(2) M	(3) Enthalpy at flue temperature T = 436 (Btu/mole)	(4) Enthalpy at ambient temperature T = 76 (Btu/mole)	(5) Δh (Btu/mole)	(6) Flue gas loss (Btu/lb)
CO_2	.074	44	7555	4015	3540	5.95
O_2	.158	32	6530	3718	2812	13.88
N_2	.760	28	6240	3722	2518	68.35
CO		28				
H_2O	.035	18	7196	4250	2946	5.73
Total	1.02				h Total =	93.91

(3) and (4) From Keenan and Kaye Gas Tables and Steam Tables

$(5) = (3) - (4)$

$(6) = \frac{(1)}{(2)} \times (5)$

$$\text{Percent } H_2O \text{ (by volume)} = \frac{\frac{WF_m}{18}}{\Sigma \frac{(1)}{(2)}} \times 100 = \_\_\_\_\_\_ \text{ percent}$$

Flue Gas Loss (continued)

$EN_{stack} = M_{20} \times h$ total

$EN_{stack} = 2.226 \times 10^6 \times 93.91 = 209.04 \times 10^6$ Btu

Blowdown Loss

102,281 lb water

3.07×10^6 Btu

Radiation/Convection Loss

The calculation for the December test indicated a loss of 1.15×10^6 Btu/hr operation. This figure was applied to the November test, giving a calculated R/C loss of 77.02×10^6 Btu.

DAT

FILME

7